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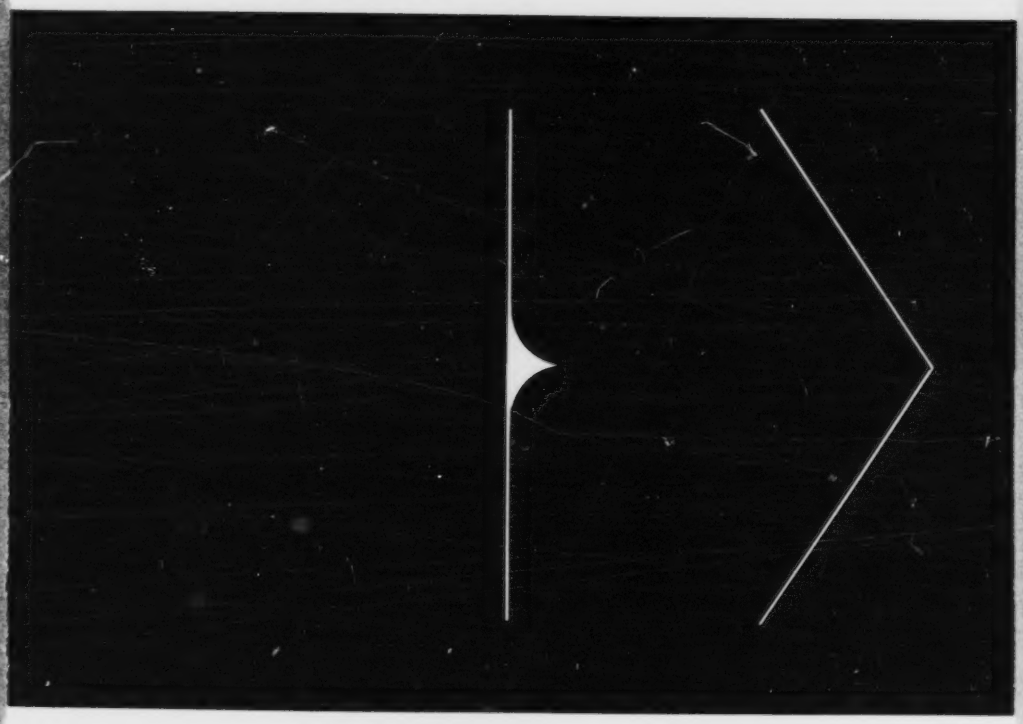

THE LIGHT-RAPID COMFORTABLE (LRC) TRAIN AND THE INTERMEDIATE CAPACITY TRANSIT SYSTEM (ICTS)

RESEARCH REPORT NO. 84

I. A. LITVAK AND C. J. MAULE

DECEMBER 1982

THE LIGHT-RAPID COMFORTABLE (LRC) TRAIN

AND

THE INTERMEDIATE CAPACITY TRANSIT SYSTEM (ICTS)

Two Case Studies of Innovation in the Urban Transportation Equipment Manufacturing Industry

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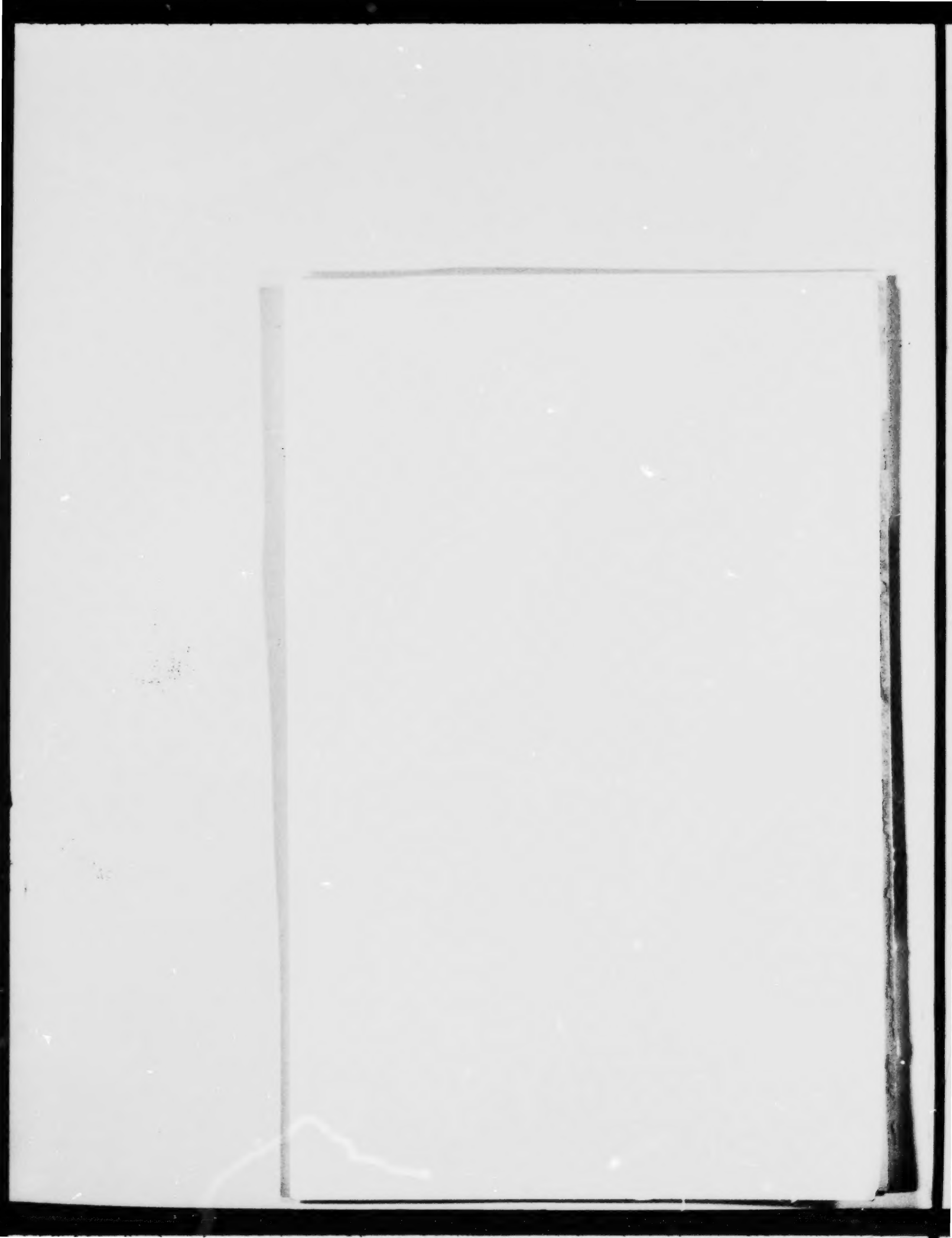

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ABSTRACT

The process of innovation in the urban transportation equipment manufacturing industry in Canada is examined in the context of two case studies, which provide an historical reconstruction of the developments leading to the Light Rapid and Comfortable (LRC) train and the Intermediate Capacity Transit System (ICTS). Special attention is drawn to the role of federal, provincial, and municipal governments, the establishment of consortia of firms from the public and private sectors, and the need to develop a systems approach to successful innovation in the field of urban transportation. The study also provides an overview of the urban transportation equipment industry in Canada as a background to the two case studies.

CHAPTER 1

INTRODUCTION

The purpose of this paper is to examine the process of innovation in the urban transportation equipment manufacturing industry, principally by means of two case studies. The industry is one in which the customers are almost entirely provincial and municipal governments, while the suppliers are mainly firms in the private sector. The process of innovation, at least at the applied stages, has typically been financed by governments, which have used a variety of institutional arrangements to promote innovation and to share the associated technical and marketing risks. It will be shown that the literature dealing with the 'innovation cycle' or the 'stages of the innovation process', has to be adapted to the institutional characteristics of this industry.

In Chapter 2 of the paper, an overview is presented of the urban transportation equipment manufacturing industry in order to arrive at a manageable definition of the industry for the purposes of discussing innovation. A preliminary listing of the first tier (vehicle) manufacturers, and second tier (vehicle components and subsystems) manufacturers is provided, together with a description of the buyers. In Chapter 3, an outline of the economics of innovation, as it has appeared in the literature of industrial organization and in a Transport Canada discussion paper is set out, together with a statement of the jurisdictional problems associated with the funding of urban transportation research and development in Canada, and a note on the way in which the existing industrial structure may affect the undertaking of

innovation. This chapter ends with an introduction to the two case studies.

The two cases selected for study are the Light Rapid and Comfortable (LRC) train (Chapter 4) and the Intermediate Capacity Transit System (ICTS) (Chapter 5). The ICTS is clearly an urban transportation system, and the LRC train is consistent with the definition of urban transportation as "the movement of people and goods into, out of, through and within urban centres", and with the commuter rail option shown in Figure 1. The LRC train also falls into the intercity transportation category, but as a Transport Canada discussion paper notes:

> Developments in the urban transportation field most often find application in intercity systems and vice versa. It is very wasteful, if not impossible, to consider research and development for two types of transportation in complete isolation.[1]

Other reasons for selecting these two systems are the fact that the technological development can be traced through the stages of the innovation process as set out by Transport Canada, some of the same firms are involved in both cases, and there is involvement by federal, provincial and municipal governments. The role of governments means that there are some special factors to consider in the process of innovation in this industry.

Summary observations on the two cases are included in Chapter 6. The summary also relates the findings to the literature on innovation, dealing with the factors which assist or impede the process in the urban transportation equipment manufacturing industry.

METHODOLOGY

There is extensive precedent for using the case study approach to examine the process of innovation and technological change. One of the pioneer studies was undertaken by Jewkes, Sawers and Stillerman in 1958 on The Sources of Invention[2] in which summaries of fifty case histories are presented, many of which are based on earlier studies by historians, economists and scientists. Subsequently, innovation and technology have received intensive examination including the use of case studies.[3]

In the present study the case approach was used as a method of undertaking an historical reconstruction of the process of innovation and the development of technology which took place over a number of years. The use of personal interviews together with secondary sources of information such as reports, studies, submissions for funding, speeches and testimony to governments permitted the collection of data from a variety of sources. There were many parties involved in each of the case study projects, their interests differed as did their perception of events, especially events which took place some years ago and which could be viewed with the benefit of hindsight. The research required that the authors evaluate the views and perceptions of the participants, especially where there were conflicting statements. In fact differences of opinion provided the opportunity to learn further details and raise more questions. It is not claimed that all the biases have been eliminated, but the extensive discussion of the cases has reduced the extent of the problem, which is inherent in case studies of this nature.

The factual information on the industry and on the

two cases has been read and checked by persons familiar with the details. The authors would like to express their appreciation to officials in the federal government, and in the provincial government of Ontario, and to executives of Alcan, Bombardier, Canadian National Railways, Dofasco and the Urban Transportation Development Corporation for their assistance in providing information and commenting on the accuracy of the factual material in the case studies in Chapters 4 and 5, and on the industry in Chapter 2.

FOOTNOTES TO CHAPTER 1

1. Discussion Paper, Transport Canada, Policy for Transport Canada Participation in Urban Transportation Research and Development, Sept. 27, 1979, p. 5.

2. Sources of Invention (London, Macmillan & Co., 1962).

3. Alfred D. Chandler, Strategy and Structure: Chapters in the History of the Industrial Enterprise (Cambridge: MIT Press, 1962); W.S. Comanor, "Research and Competitive Product Differentiation in the Pharmaceutical Industry in the United States", Economica, N.S., Nov. 1963, 31 (124), pp. 372-84; L.L. Deutsch, "Research Performance in the Ethical Drug Industry", Marquette Business Review, Fall 1973, 17(3), pp. 129-43; C. Freeman, "Research and Development in Electronic Capital Goods", National Institute Economic Review, Nov. 1965, 34, pp. 40-91; C. Freeman, "Chemical Process Plant: Innovation and the World Market", National Institute Economic Review, August 1968, 45, pp. 29-57; Burton H. Klein, Dynamic Economics, (Cambridge, Mass.: Harvard University Press, 1977); C. Layton, C. Harlow and C. De Hoghton, Ten Innovations: An International Study on Technological Development and the Use of Qualified Scientists and Engineers in Ten Industries (London: George Allen and Unwin, 1972); A. Phillips, Technology and Market Structure: A Study of the Aircraft Industry (Lexington, Mass.: Lexington Books, 1971); David Schwartzman, Innovation in the Pharmaceutical Industry (Baltimore: Johns Hopkins University Press, 1976); W.J.J. Smith and D. Creamer, R&D and Small Company Growth: A Statistics Review and Company Case Studies, The Conference Board Studies in Business Economics No. 102 (New York: National Industrial Conference Board, 1968); David J. Teece and H.O. Armour, "Innovation and Divestiture in the U.S. Oil Industry", in Teece, ed., R and D in Energy (Stanford: Stanford University Institute for Energy Studies, 1977), pp. 11-35; and Abbott P. Usher, A History of Mechanical Inventions, Rev. ed. (Cambridge, Mass.: Harvard University Press, 1954).

CHAPTER 2

THE URBAN TRANSPORTATION EQUIPMENT MANUFACTURING INDUSTRY

The two case studies in Chapters 4 and 5 are examples of innovation in the Canadian urban transportation equipment manufacturing industry. In order to understand the details of the cases, it is necessary to provide an overview of the salient characteristics of the industry. It will be shown that due to the nature of the industry regarding suppliers, customers, and the role of government, the process of innovation is different to that of many other industries, with the possible exception of the defense industry.[1] In the following sections, an overview will be provided of the definition of the industry, the producing firms, and the buying side of the market.

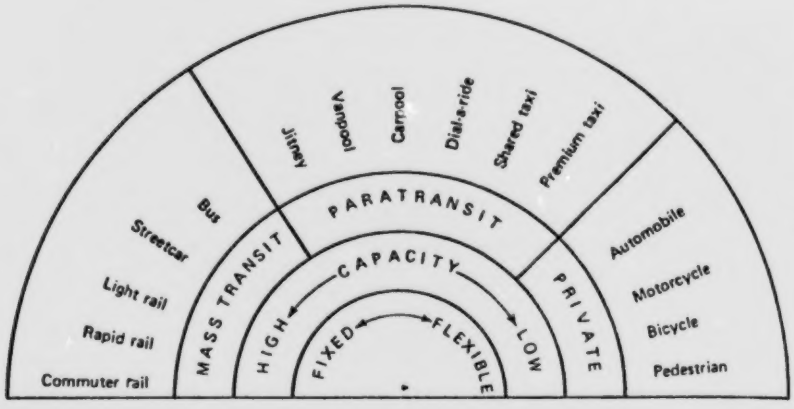
INDUSTRY OVERVIEW AND DEFINITION

The urban transportation equipment manufacturing industry consists of all those firms which provide equipment for urban transportation. The purpose of urban transportation is to move persons and goods into, out of, through and within urban centres. The emphasis of this study will be on urban transportation related to the movement of persons, although the equipment may be usable for goods as well as persons, and persons may carry goods in the course of their travels, as in the case of shopping trips.

There is a wide variety of urban transportation modes - see Figure 1 - which vary considerably in terms of the type of equipment required. These modes can be substitutes for each other, with there being differences

FIGURE 1

SPECTRUM OF OPTIONS IN URBAN TRANSPORTATION MODES



SOURCE: G.E. Gray and L.A. Hoel, Public Transportation Planning and Management, (New Jersey, Prentice-Hall, 1979), p. 206.

in the nature and extent of substitutability. For example, the bicycle may be a poor substitute for the distance covered by commuter rail, but the carpool may be a close substitute for the bus. In this example, the substitutability depends on the distance covered. However, there are different methods of substitution to contemplate, and when these are recognised the dimensions of the urban transportation equipment manufacturing industry are enlarged.

The service provided by much of the urban transportation industry is to move people to their place of work. Since the time of the industrial revolution, there has been a growing tendency for labour to move to centralised work places, and urban transportation has provided one means of conveyance. If, on the other hand, work could be moved to labour, instead of labour to the work place, then there would be a reduced need for urban transportation as we now know it. In its place would be required the equipment to provide the necessary means of communicating or shipping work to the worker. Transportation and communications thus become services which can be substituted, and a wider definition of the urban transportation equipment manufacturing industry would include the firms producing certain types of communications as well as transportation equipment. Some examples of work being transported to labour, as opposed to labour to the workplace, already exist, especially in typing, secretarial and programming occupations.[2]

A more traditional view of the urban transportation equipment manufacturing industry is to consider it as containing those firms which produce vehicles, the infrastructure for vehicles, and control and communication systems.

> In Canada, urban transportation equipment is not identified individually or collectively by SIC, because it includes products from many current groupings. Included in the range are mini-buses, buses, trolley-buses, streetcars and intermediate capacity systems, support systems for vehicle monitoring and control, computerized traffic signals, passenger and management information and communication equipment.[3]

These three sectors of the urban transportation equipment manufacturing industry, vehicles, infrastructure and control and communications experience different degrees of vertical integration. A bus is a collection of components such as body, engine, transmission, gear box and wheels. A vehicle manufacturer may merely assemble components purchased from other firms, produce and assemble all components, or more likely produce some components, purchase others and do the assembly work. In these terms, the urban transportation equipment manufacturing industry consists of firms producing components as well as firms doing the assembly work.

Similar examples could be drawn for infrastructure firms. The production of roads, pavements, and railway beds and lines require a combination of inputs such as engineering firms, construction firms and steel rail producers. Control and communications systems are integral parts of transportation equipment, either to control the internal mechanisms of trains, buses and cars, or to control the flow of the equipment as in the case of traffic lights and train signals. Those firms which produce components for control and communication systems are potential members of the urban transportation equipment manufacturing industry.

It would be easy, as well as confusing, to expand the definition of the urban transportation equipment

manufacturing industry to include a large number of firms, some of which could equally be considered part of other industries. Using the foregoing approach would result in a steel producer, for example, being part of the steel, automobile, appliance, pulp and paper and construction industries, in addition to its membership in the urban transportation equipment manufacturing industry. The definition of the industry will have to be narrowed, but an appreciation of the broader picture is necessary in order to understand questions of innovation in urban transportation, which is the central focus of this paper. The experience with innovation in one sector may spill over to other sectors.

Approaches to Innovation

There is a long list of problems in urban transportation which require resolution such as congestion in urban areas, land use, air and noise pollution, increased energy costs, the social and economic costs of expanding facilities such as highways and downtown parking, and the overdependence on automobiles which is depriving certain people, such as the aged, disabled and young, of an adequate level of mobility. Innovation in urban transportation can help to solve these problems by combining the expertise of equipment manufacturers and related transportation specialists.

There are three basic approaches to the use of innovation to solve some of the urban transportation problems. First, new ways can be devised to use the existing transportation facilities more efficiently. Second, new equipment can be developed. A third approach is to develop new equipment and new systems and facilities. The first approach corresponds to the use of vanpools and special bus lanes on existing highways, while the

second and third are illustrated by the development of a magnetically levitated (maglev) transportation system or a tracked air cushion vehicle. Innovation in the urban transportation equipment manufacturing industry leading to increased efficiency may result from actions which affect the manufacture of equipment used in urban transportation, and from actions which lead to the more effective use of equipment. In the latter case, a transportation systems analyst may be the key ingredient leading to innovation.

This detour into aspects of urban transportation has been made for two reasons. First, an industrial organization study of the urban transportation equipment manufacturing industry is different to a similar study of the chemical or steel industries, because of the wide range of equipment which is used in urban transportation - from bicycle to bus to subway. The industry cannot be defined in terms of a piece of equipment, but rather in terms of the service which the equipment provides. In order to present a manageable focus for discussion, some limit has to be placed on the number and type of firms included in the industry. Second, innovation in urban transportation is concerned with reducing the private and social costs of moving people in an urban setting. Resources devoted to innovation may affect both the design of equipment as well as the use of the equipment in a transportation system.

Narrowing the Definition

The Department of Industry, Trade and Commerce (DITC), in 1977, divided the urban transportation equipment manufacturing industry into two segments, vehicle systems, and electric and electronic systems. Vehicle systems

were reported to consist of over 300 companies divided into three tiers. The first tier was made up of eight firms which produced vehicles used in Canadian transit systems. In the second tier, were 20 companies which produced major components or subsystems for these vehicles. The third tier consisted of about 240 companies which provided materials and components for the 28 first and second tier companies, and at least 36 major civil works contractors which had infrastructure expertise. In the electric and electronic systems segment, it was noted that there was little available current or historical data.[4]

In the context of the present study, attention will be focussed on the first and second tier companies which are part of the vehicle systems segment. Although the firms were not identified, information from public sources provides a reasonable approximation of the firms which are likely to have been included.[5]

FIRMS AND MARKETS

Vehicle Manufacturers

There are about ten firms which can reasonably be included as first tier vehicle manufacturers. Railway vehicles are produced by three firms in Canada, Bombardier, Versatile Vickers and Hawker Siddeley. In addition, the Ontario government-owned Urban Transportation Development Corporation (UTDC)[6] has developed a light rail vehicle, the ICTS: the manufacturing of the vehicle will be contracted out to private firms, but marketed through UTDC. Bombardier and Versatile Vickers are Canadian-owned while Hawker Siddeley is British-owned. The sales, asset and employment size of these firms do not reflect their involvement in vehicle production because they

produce other products as well, and their sales of vehicles are not separated out from total sales. In addition, vehicle sales for any one year can be misleading, because orders tend to be lumpy, and the year chosen for recording sales might be one in which a large number or very few vehicles were sold.

Bombardier, for example, has three product sectors: transportation, which includes rail, diesel products and mass transit; recreational products; and industrial equipment and products. Hawker Siddeley's principal interests are in the aircraft industry, but it produces rail vehicles in a plant at Thunder Bay acquired from Canadian Car and Foundry Ltd. Bombardier employs about 6500 persons overall, but only about 1000 may be involved in vehicle production at any given point in time.

There are four bus manufacturers in Canada, General Motors (GM), Flyer Industries Ltd. (owned by the Manitoba government), Ontario Bus Industries (Canadian-owned), Motor Coach Industries Ltd. (owned by Greyhound in the U.S.) and Prevost Car Inc. (Canadian-owned). The first three firms produce buses for urban transportation use, although there are differences between the firms in size, type of bus and degree of vertical integration. General Motors produces about 1200 forty-foot transit buses a year using many components manufactured by GM-affiliated companies. Their Canadian bus plant is now in Quebec, but was previously located in London, Ontario. General Motors is the largest Canadian manufacturer of diesel transit buses, and this location is GM's sole North American source for conventional diesel transit coaches. Flyer Industries produces about 500 forty-foot transit buses a year, with a work force about the same size as GM employs to produce over twice this number.

Flyer Industries is primarily an assembly operation for components produced elsewhere. Ontario Bus Industries produces about 100 thirty- to thirty-five foot, Orion transit coaches a year and is also primarily an assembly operation.

Motor Coach Industries and Prevost Car Inc. produce intercity highway and deluxe charter coaches, although some of these may be used for commuter and airport service. A fifth bus manufacturer, Travel Mate Ltd., has produced 24- to 35-seat passenger buses for use in the dial-a-bus service and has done design work for UTDC.[7]

A further point to note about bus manufacturing is that the number of engine, transmission and axle manufacturers may be fewer than the number of bus assembly firms. Thus, most of the listed bus manufacturers may build the body and assemble components produced by other firms. This also tends to be the case for the three rail manufacturers.

The process of innovation in vehicle manufacturing tends to be associated with the design capability of both the listed manufacturers and those firms which supply component parts. For example, Bombardier and Hawker Siddeley have a design capability, while Vickers tends to produce rail vehicles based on acquired design.

The importance of urban transportation equipment to the operation of each firm differs, as does the type of manufacturing and innovation activity undertaken. When the focus is placed on the total company, including foreign parents and subsidiaries where appropriate, the relative importance of the firms' urban transportation equipment operations is significantly less.

Component Manufacturers

The problem of identifying component (second tier) manufacturers and describing their urban transportation activities is more complicated than dealing with vehicle manufacturers. The components produced for urban transportation may be a small part of the firm's sales - half of one percent is Dofasco's estimate of transportation-related sales.

The firms listed in Table 1 produce a wide range of products from seats to windows to air conditioners, insulators and electrical equipment. Alcan's interest in the industry is primarily as a means of selling aluminum. However, in the process it has developed a design capability which has been a critical ingredient for innovation leading to the LRC train. ITT-Canada's interests are related to an ITT-affiliated company in Germany, Standard Electric (SEL), which developed a train control system for freight railroads in Germany, and which has extended this development for use in the UTDC-funded ICTS project. SEL Canada is the ITT subsidiary in Canada which can be identified with the urban transportation equipment industry.

The manufacturers of electric propulsion systems include Brown Boveri Canada, Canadian General Electric and Westinghouse Canada Inc. Differences exist between these firms in terms of the amount of manufacturing done in Canada. Some firms may import the motors or components, while others manufacture them in Canada. Thus, there will be differences in the amount of value-added undertaken in Canada, and differences in the opportunities for innovation to be performed in Canada. Firms which import components will tend to import the results of innovation performed outside Canada.

TABLE 1

SELECTED COMPONENT MANUFACTURERS IN CANADA

Name	Ownership	Principal Transportation Equipment products
Alcan Canada Products Ltd.	Canadian	Aluminum vehicle bodies and components
B.G. Checo	French & Canadian (Que. Gov't.)	Lighting, fare control systems
Beclawat Ltd.	Canadian	Windows and doors
BBC, Brown Boveri Canada Inc.	Swiss	Electric motors and chopper controls
Canadian General Electric Ltd.	U.S.	Electrical equipment
Dofasco	Canadian	Railway rolling stock
Garrett Manufacturing Ltd.	U.S.	Chopper controls
Glenayre Electronics Ltd.	Canadian	Signalling equipment
Insul-8 Corp. Canada Ltd.	U.S.	Pantagraph, rail coverboard
ITT-Canada Ltd.	U.S.	Control systems
Otaco Inc. Ltd.	Canadian	Seating
Sheldon Engineering Ltd.	Canadian	Fans, blowers, air conditioners
SPAR Aerospace Ltd.	Canadian	Gear boxes, transmissions, axles
Spaulding Fibre Canada Ltd.	U.S.	Insulators
Stone-Pratt Electrical Canada Ltd.	U.K.	Ventilating and air conditioning systems
Vapor Canada Ltd.	U.S.	Electrical components
WABCO	U.S.	Air brakes
Westinghouse Canada Ltd.	U.S.	Electrical components

SOURCE: Department of Industry, Trade and Commerce and Annual Reports.

Dofasco's interests are mainly in the development of trucks for freight and passenger railway rolling stock. The company designed the tilt mechanism for the LRC project and is working on a steerable truck for use by UTDC in the ICTS project. Dofasco has, of course, built heavy rail rolling stock for many years.

These examples of the component manufacturers' involvement in urban transportation equipment illustrate the difficulty of identifying the firms involved. Once identified there are considerable differences in the importance of this market to the firms, the type of manufacturing they do, and the scope and nature of the innovation which can be undertaken. For example, Alcan Canada Products Ltd. had 1981 sales of $744 million, a small part of which is transportation related, but it has developed a design capability in the use of aluminum in transportation equipment.[8]

Undoubtedly, there are other firms which could be added to the list, such as the steel companies in Canada and the steel wheel division of Hawker Siddeley. One firm frequently mentioned is Canadair, a goverment-owned aircraft manufacturer, which became involved as project manager and vehicle designer for the ICTS. When the aircraft business picked up, this capability was sold off as Metro Canada Ltd. to UTDC and now resides primarily in Kingston. SPAR Aerospace, which is listed in Table 1, is another aircraft-related firm, which at one time had greater involvement in ground transportation. SPAR worked on the linear induction motor for the ICTS, and while it still has experience in the area, it has withdrawn from this particular project.

Another major actor is the Ontario government's UTDC,[9] created in the early seventies as part of Ontario's urban transit policy. The corporation has produced a steady flow of technology, and was not originally intended to be a manufacturer. This may change as a result of the development of the ICTS project and its adoption by the City of Vancouver. Some manufacturing, perhaps only assembly and testing, may be done at the Kingston site. At present, UTDC provides research design and development services, advisory services, hardware products and project implementation through a subsidiary, Metro Canada, as well as the licensing of products. Hardware products developed to date include the Canadian Light Rail Vehicle (CLRV), ICTS and Steerable Trucks. UTDC is undertaking research and development on hydrogen research, flywheel projects and truck retrofit projects, contracts have been received for transit management advisory services, and technology has been licensed to Japan and the United Kingdom.

Other Firms

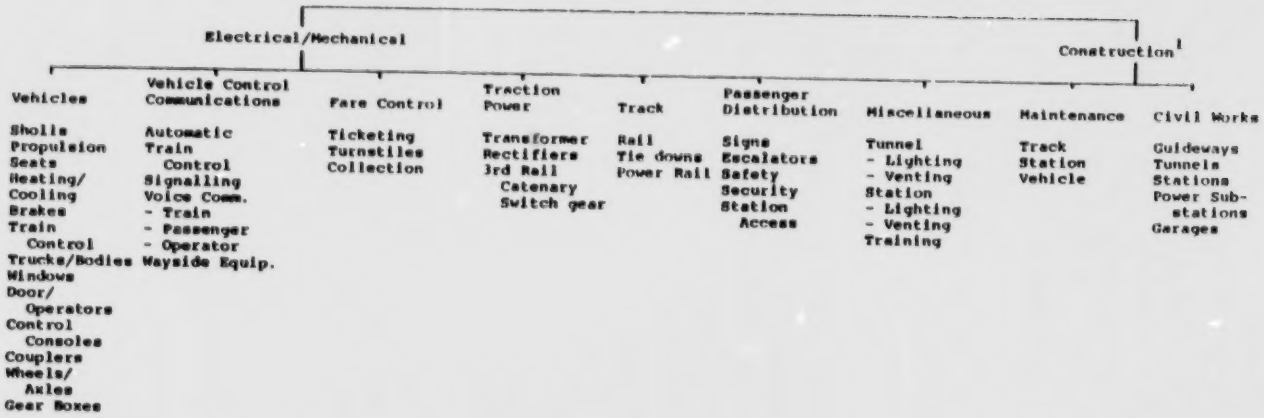
An extension of the first-and second-tier firms are the consulting firms which service the manufacturers as well as the transit authorities which are the customers for the equipment. The consulting group includes firms such as The IBI Group, Systems Planning and Equipment Co. and Comdat Telecommunications Inc. However, once consultants are included in the list of equipment manufacturers, the discussion moves away from the more narrowly defined description of the industry. One problem is that one manufacturer may be vertically integrated and own its own engineering-design or consulting capability, while another may contract out with individual consultants. This type of expertise may be critical for the process of innovation.

The boundaries of the urban transportation equipment manufacturing industry are elusive at the best of times, and especially when innovation is the focus of interest. The vehicle manufacturers and component manufacturers listed here understate the number of firms in the industry. The size of these firms is typically much larger than their interest in urban transportation because of the diversified range of products produced. One listing of system components for urban transit is shown in Figure 2. The system contains vehicles and their components, vehicle control systems, power units, guideway infrastructure and passenger collection and distribution facilities. It can be readily appreciated that there are a large number of potential manufacturers for transit systems, as well as a large number of places where innovation can occur.

In fact, not only is there no way of listing precisely the firms in the industry, there is no clear-cut definition of what constitutes urban transportation. LRC trains were designed for intercity travel, but may be used to transport commuters, a service which the GO trains perform for Toronto; air transportation, especially STOL aircraft and helicopters, may be used for some forms of urban transportation; in Vancouver, ferries have been developed to transport commuters from North and West Vancouver to the downtown area; and the automotive manufacturers are perhaps the main producers of urban transportation equipment, which, when used as paratransit vehicles, are intermediate between private and mass transit. These examples serve to illustrate the difficulty of deciding which firms to include in the industry and how innovation is to be assessed.

FIGURE 2

URBAN TRANSIT SYSTEM COMPONENTS



[1] Normally exceeds 50% of total system costs

The Buyers

The customers of the urban transport equipment manufacturing industry tend to be the public transit authorities of provinces and municipalities. The buying practices of these authorities and the assistance provided by government create conditions in the equipment market which affect the process of innovation.

The equipment purchases tend to be large unit items such as buses and rail transit vehicles. Buses can be bought one unit at a time and are used in conjunction with an infrastructure of roads and streets which are separately funded. Rail transit systems tend to be far more expensive and the vehicles (trains) are only one part of the total cost of the system. The economic significance of each type of purchase decision (bus versus rail) is substantially different in terms of cost and funding.

The Canadian Urban Transit Association (CUTA), whose membership is made up of most of the urban transit systems in Canada, reports some basic statistics on systems, equipment and their use. In 1979, the 66 urban transit systems which were members of CUTA served a total population of 13 million persons. The passenger vehicles owned by these systems consisted of,

Motor Buses (2,163 radio-equipped)	9,445
Trolley Coach	559
Light Rail Vehicle (streetcar)	375
Heavy Rail Vehicle (subway)	1,377
Dial-a-bus Service	109
Total Vehicles	11,865

The 66 systems carried 1.2 billion revenue passengers for a total of 392 million miles or 3.1 passengers per mile - Table 2. Since 1977, there has been a decline in

TABLE 2

CANADIAN URBAN TRANSIT ASSOCIATION REVENUE PASSENGERS, AND MILES OPERATED, 1950-1979

Year	Number of Systems	Total Revenue Passengers (000's)	Total Miles (000's)	Passenger Per Mile
1950	33	1,395,671	248,474	5.6
1955	32	1,119,273	184,267	6.1
1960	34	973,153	184,321	5.3
1965	39	941,540	198,126	4.8
1970	49	979,728	241,979	4.0
1971	47	971,533	246,157	3.9
1972	54	1,048,008	260,108	4.0
1973	57	1,051,972	279,070	3.8
1974	57	1,082,271	292,053	3.7
1975	61	1,158,933	329,204	3.5
1976	64	1,214,038	352,906	3.4
1977	64	1,222,722	366,058	3.3
1978	65	1,218,084	383,648	3.2
1979	66	1,205,311	391,537	3.1

SOURCE: Canadian Urban Transit Association, Fact Book 1980, p. 71.

the distance which each passenger has travelled, despite an increase in the number of miles that the transit vehicles have travelled. Innovation and technological change, as incorporated in an Intermediate Capacity Transit System (see Chapter 5), may be one way of improving the financial situation of the transit authorities.

In 1979, the 66 transit systems purchased 650 motor buses, 620 of which had a seating capacity of 40 or more, 11 light rail vehicles (streetcars) and 52 heavy rail vehicles. Over the years, there has always been a demand for motor buses, especially those with 40 or more seats, but the demand for trolley coaches, light rail and heavy rail vehicles has been intermittent.[10]

The purchasing procedures of the transit systems will affect the operations of the vehicle producers. OC Transpo in Ottawa has published, from time to time, details of its purchasing procedures for buses.[11] Over the years, OC Transpo has developed statistics on the costs of operating and maintaining each type of bus, including details of the time the bus spends out of revenue service and the costs of operating at peak and off-peak times. All these factors are taken into account when a decision is taken to retire a bus or to purchase a new bus. The price of the bus is thus only one factor to be considered. In practice, it appears that OC Transpo, as of 1981, purchases all its diesel buses from GM, and that Flyer Industries cannot meet its requirements in terms of price and non-price conditions.

The purchase of light rail systems for urban transportation use are multi-million dollar items. For example, UTDC has stated the introduction of its ICTS into Hamilton will cost about $110 million, and that

similar systems in Los Angeles, Miami and Detroit are estimated to cost $130 million, $195 million and $165 million respectively.[12] Because of the sums involved, urban transit financing has been undertaken with the help of government subsidies which vary by provinces. In general, the subsidies relate to capital costs, operating costs and other costs such as planning, and experimental and demonstration projects.[13]

The provincial input into purchasing decisions led to the cities of Edmonton and Calgary purchasing European-manufactured light rail commuter trains, at the same time that there existed a manufacturing capacity in Ontario and Quebec. Government subsidies and purchasing policies have had two types of effect: first, they have assisted the transit authorities in purchasing equipment, but second, they have tended to disperse the equipment orders between a number of Canadian and foreign suppliers. The latter effect may not be conducive to the undertaking of innovation by Canadian firms, which are unable to gain access to a large enough domestic market.

The Market

On the buyer side of the market, the nature of purchasers, their buying practices and the method of funding tend to fragment the market when sales in Canada are considered. Conditions in the export market, especially in the U.S. market where 'Buy America' provisions exist, tend to confound the problem of fragmentation. The 'Buy America' clause of the Surface Transportation Act requires that all capital equipment purchased with federal funds in the U.S. must have at least 50 percent U.S. content.

The selling side of the market is also fragmented,

partly due to the nature of the product, since an urban transportation vehicle is an assembly of components and systems. As noted above, there tend to be a large number of potential manufacturers involved, they are geographically dispersed, and the items which they produce for urban transportation may be only one part of a more diversified product line.

Some of the producers are also foreign subsidiaries where the 'miniature replica' effect may exist, with short production runs and high cost operations.[14] These subsidiaries may import under license the technology used in urban transportation and adapt it to Canadian needs. These firms may not respond to government support for research and development which requires development of products in Canada. Parent companies tend not to allow their subsidiaries to accept research and development support on these terms, and may further constrain the companies from exporting to third country markets. For this reason, some subsidiaries do not accept government research and development assistance.

The urban transportation equipment market reveals in miniature many of the problems of Canadian confederation - uncertain federal-provincial jurisdictional boundaries, provincial interests in promoting local industries, foreign ownership of manufacturing firms, and use by Canadian-and foreign-owned firms of foreign technology. At the same time, there is a manufacturing capability in Canada of domestic-owned and foreign-owned firms that could participate in a very large projected world market for urban transit in the next two decades.

In sum, there are aspects of the urban transportation

equipment manufacturing industry in Canada which impede research and development. Some aspects can be altered by unilateral federal action, but most require some degree of intergovernmental (federal-provincial) cooperation. The two case studies illustrate how this cooperation has worked in the past and where improvements might be made.

FOOTNOTES TO CHAPTER 2

1. See F.M. Scherer, "The Aerospace Industry", in W. Adams (ed.), The Structure of American Industry, 4th Edition (New York, MacMillan & Co., 1971), pp. 335-379.

2. Business Week, January 26, 1981.

3. Department of Industry, Trade and Commerce, Task Force Report, Urban Transportation Industry in Canada (Ottawa, 1977), p. 1.

4. Department of Industry, Trade and Commerce, op.cit., pp. 2 and 7.

5. Handbook of the Canadian Urban Transit Association Fact Book, 1980, Department of Industry, Trade and Commerce Release, and Mass Transit, Feb. 1981.

6. UTDC was originally called OTDC, or the Ontario Transportation Development Corporation. Both names are used in this study.

7. Brown Boveri of Canada Ltd. is another new entrant in the bus manufacturing sector of the industry.

8. Alcan Aluminum Ltd., Annual Report 1981, p. 19.

9. Also mentioned under first tier vehicle manufacturers.

10. See Canadian Urban Transit Association, Fact Book 1980, p. 76.

11. See H. Chaput, Report on Bus Renewals and Replacement Programs for the Ottawa Transportation Commission (Ottawa, 1960); and OC Transpo, Overview of Equipment Department and Bus Maintenance 1980 (Ottawa, April 1981).

12. K.W. Foley presentation to Senate of Canada, Standing Committee on Foreign Affairs, Oct. 16, 1980, p. 11:21. Hamilton is now not going ahead with this project. One estimate based on industry source is for a world market for urban transit, mainly rail and bus, of $180 billion by 1985.

13. For a listing of the federal and provincial assistance programs for urban public transit financing, as of 1978, see S.K. Bhattacharyya, "Urban Public Transit Subsidy Levels and Effects", Working Paper for the Ministry of State for Urban Affairs, and Urban Transportation Research of Transport Canada, Ottawa, 1979.

14. The miniature replica effect refers to situations where the foreign subsidiary in Canada produces, on a smaller scale, the same range of products produced by the parent company abroad. However, while the parent company may produce the products in separate plants, the subsidiary tends to produce a wider range of products in one plant. Costs tend to be higher in the subsidiary for two reasons: the subsidiary's plant is smaller (plant-specific diseconomies) and the output is more diversified (product-specific diseconomies). See Foreign Investment in Canada (Government of Canada, 1972), pp. 405-411.

CHAPTER 3

RESEARCH AND DEVELOPMENT AND INNOVATION

RESEARCH FUNDING AND JURISDICTION

The research and development capability and activity regarding urban transportation in Canada can be described in part by the known transportation laboratories and testing facilities in Canada, and the projects funded by government through the Transportation Development Centre (TDC).[1] The Roads and Transportation Association of Canada lists 83 research organizations involved with rail, road and intermodal transportation. These categories have been used to approximate the number of organizations which could be involved with urban transportation. The categories excluded are air, air cushion, marine, off-road, pipelines and space.

The 83 organizations are distributed as follows:

Research on

Road only	36
Rail only	5
Road and Rail only	19
Intermodal only	1
Road and Intermodal	2
Rail and Intermodal	4
Other* only	5
Road and Other	5
Rail and Other	1
Road, Rail and Other	2
Road, Rail and Intermodal	3

*The other category includes miscellaneous organizations such as Environment Canada, Atmospheric Environment Service, and the Transportation Safety Research Institute.

More than half the organizations are located in Ontario fairly equally divided between consulting firms, the federal and provincial governments, universities and

other private firms. About 15 percent of the firms are in Quebec, 20 percent in the Prairie provinces and the balance equally divided between British Columbia and the Atlantic provinces. Overall, consulting firms account for about 25 percent of the total, other private firms for about 40 percent and the remainder are equally divided between government departments and agencies and universities.

Transportation Development Centre

The projects funded by Transport Canada through the Transportation Development Centre (TDC) in Montreal from 1978 to 1980 are listed in the Centre's Project Directories. These 47 projects are described by TDC as relating to Surface Technology and include projects such as 'intercity road technology', innovative urban transit technology, propulsion and energy conservation and tracked levitated vehicle technology. Excluded are projects listed as Railway, Air and Marine Technology. The association of urban transportation with the Surface Technology category is somewhat arbitrary, but does indicate the types of urban transportation research and development that have been funded and who the contractors have been.

In the three-year period, TDC has been involved in funding the 47 projects for a total of more than $10 million. The projects have been undertaken by consulting firms (17), transportation firms (12), universities (9), governments (8) and in-house (1). Funding has been provided either by TDC alone or jointly with other government or private organizations. About 60 percent of the $10 million was funded by TDC and the remainder came from other sources.

The UTDC was the principal contractor in four TDC projects, Bombardier in three and Queen's University (CIGGT) in three cases. The three largest projects were for the concept definition of an ICTS (Bombardier $1.5 million), the design of an ICTS lightweight bogie (Bombardier and others $1.8 million in total with TDC providing $540,000), the evaluation of an electric vehicle (Dillworth, Secord, Meagher & Associates Ltd., $1.4 million in total with TDC providing $560,000), and a diesel/flywheel hybrid drive train (UTDC, $1.3 million in total with TDC providing $444,000). The 47 projects were assigned to the rail mode in 9 cases, road in 30 and other in 8 cases: the other category mainly relates to maglev transportation systems.

The Question of Jurisdiction

"In terms of the division of powers in Canada between the federal and provincial governments, responsibility for most urban transportation activities is vested with the provinces, and through them to the municipalities".[2] Nonetheless, the federal government has become involved in urban transportation as a result of a number of related responsibilities. First, the federal government has the responsibility to develop a safe, effective and efficient national transportation system. Cities are part of this system and contain terminals which link interprovincial and international systems where the federal government has jurisdiction. Furthermore, the federal government has responsibility for economic development and for energy self-sufficiency, both of which are affected by urban transportation systems, as well as for social factors such as providing for the transportation needs of the elderly, the handicapped and the young.

All these responsibilities can be promoted by the application of research and development, and the federal government, since 1970, has used various programs to promote innovation in urban transportation equipment and systems. In 1974, the federal government announced a program of capital assistance for urban commuter and transit services. The funding level of the program was stated in 1975 to be $100 million, but the program was not implemented. In its place an Urban Transportation Assistance Program was announced in 1977 and implemented by Transport Canada in 1978 with funding of $230 million over five years to be allocated to the provinces. Funds can be used for urban transportation equipment, infrastructure facilities, studies, and for railway relocation and grade crossings, but not specifically for research and development projects. In practice, the funds have been spent on projects, such as grade crossings, which have high provincial payoffs, and not for technology-related projects which might have high national as well as provincial payoffs.

Urban transportation research and development has been promoted since the early 1970s through the Urban Transportation Research Branch of the Transportation Development Centre. The Branch was closed in 1979 after a period of five years in which a total of $12 million had been spent by TDC and other government and private interests on urban transportation research and development. The reasons for the closure were general fiscal restraint and the view that such research and development was a provincial responsibility. The National Research Council has also assisted in the development of subsystems and components for urban transportation.

Despite this background of support and withdrawal of support for urban transportation research and development, by 1980, the pressure was on again for the federal government to act. The DITC Task Force Report on the urban transportation equipment manufacturing industry in 1978 recommended that the federal and provincial governments jointly establish and implement a national urban transportation policy with supportive procurement, research and development and industrial development programs; the Road Transport Association of Canada recommended in 1980 that a federal-provincial body be established to plan, coordinate, fund and manage urban transportation research and development; the Canadian Urban Transit Association made a similar recommendation in 1980; and the Ministry of State for Science and Technology identified transportation research and development in general as one of four priority areas for support in order to raise research and development expenditures to 1.5 percent of GNP, as a way of revitalizing Canada's manufacturing industries.

In sum, the jurisdictional issue has led to there being intermittent federal government support for urban transportation research and development. Despite this situation, some notable achievements have occurred as a result of federal, provincial and joint government funding. Developments include the Hawker Siddeley double decker commuter car, the UTDC light rail car, the linear induction motor developed by SPAR Aerospace, the LRC train, and the steerable truck units used in the ICTS. It is also noteworthy that the principal associations involved in urban transportation are pressing for greater assistance for research and development.

ECONOMICS OF INNOVATION

The process of innovation has been studied, because of the association of innovation with economic growth, through improvements in productivity and efficiency of products, processes and forms of organizing economic activity. The innovation process has been conceptualized in a number of ways, each of which stresses a different aspect of the process. One approach lists the stages in the process as,

1. Basic research - investigation undertaken to gain knowledge for its own sake.
2. Applied research - investigation undertaken to gain knowledge in order to obtain some specific commercial application.
3. Development - the translation of technical and scientific knowledge into concrete new products and processes.[3]

Movement through the stages implies a shift from pure scientific research to commercial application. This does not mean that each stage is necessarily discrete, but rather that each stage may involve different motivations on the part of the actors involved and may require different circumstances for successful completion. For example, the level and type of risk may vary between stages, as may the financial requirements and the importance of vertical integration.

A second and similar approach uses the terms invention, innovation and diffusion,[4] where invention solves the technical problems, innovation involves the first entrepreneurial attempt to apply the invention, and diffusion relates to the widespread use of the innovation. A variation of these two approaches is to focus not on the knowledge, but more on the functional

activities which have to be performed, namely, invention, entrepreneurship, investment and development.[5] That is to say, it is necessary to combine the new knowledge with financing and entrepreneurship in order for development to occur, and for the product to be commercialised in the marketplace in the first instance, when diffusion may occur.

There has been extensive research undertaken on the economic causes and consequences of research and development. A major focus of the research has been to examine the factors associated with each stage of the process of innovation and with the relationship between stages. Issues discussed include the measurement of research inputs and outputs, the opportunity for technological change in an industry due to the basic scientific knowledge in the field, the effect of vertical integration, firm size and market structure, especially concentration and entry barriers, the availability of internally generated funds, the support provided by government procurement and subsidies, and the internal characteristics associated with the management and organization of firms. The theory and empirical findings, including the results of case studies, have been summarised in several publications.[6]

One industry case study which provides examples somewhat similar to that of innovation in the urban transportation equipment industry is the aerospace industry, or more broadly the advanced weapons and space vehicle industry. This study notes that the aerospace industry

> ...includes producers from a variety of more conventionally defined fields...It sustains an extraordinarily rapid pace of technological advance,

> attended by unusually great technological uncertainties concerning product characteristics and costs. Because of these uncertainties...special institutions have been created to shift from producers to the government what might be intolerable financial risks. When it assumes the risks of research and production, the government tends also to usurp many of the decision-making functions traditionally exercised by sellers. The end result is a set of buyer-seller relationships quite unlike those normally found in the market economy. Indeed, what goes on in the industry cannot be called private enterprise in any conventional sense; it lies in the gray area between private and public enterprise.[7]

The similarities between the aerospace and urban transportation equipment manufacturing industries will become evident in the two case studies. The historical reconstruction of the two case studies will be developed along the lines of the four stages of the 'innovational cycle' developed by Transport Canada in an examination of policies to promote research and development.[8]

Innovational Cycle

Stages		Description
I.	Concept Generation	Applied research and feasibility studies
II.	Concept Validation	Experimentation and early prototype development
III.	Product Development	Construction and testing of full scale pre-production prototype
IV.	Operational Demonstration	Demonstration and evaluation of the first production prototype models in operational service prior to (and essential for) widespread acceptance and use of the new technology.

These four stages correspond to the 'applied research' and 'innovation' stages identified in the other literature quoted, i.e., they are a magnification of

what happens during innovation. The term cycle is somewhat misleading, because the stages lead to a progression through the process and not a return to the start.

The examination of the LRC and ICTS projects will deal primarily with the four stages of the so-called innovation cycle, and will identify those factors which helped or hindered the progression through the stages. Some differences will occur. For example, Stage 1 was not as important for the LRC train as for the ICTS because of the type of technology being used, and because of previous experience gained with the use of the technology. Secondly, Stage 4 is complete for the LRC train but incomplete for the ICTS. Moreover, if successful commercial operation is viewed as being a fifth stage, then the evidence for this stage is not available for either project.

INTRODUCTION TO THE TWO CASE STUDIES

The LRC train is a new intercity passenger train conceived and developed to carry up to 350 passengers in a five-car train, at high average speeds on existing railway track structures. The initials stand for Light, Rapid and Comfortable, which are its design goals relative to existing trains. The development of the train required the adaptation of existing diesel-powered technology to the traditional means of designing passenger or rail equipment, which includes the requirement to use existing roadbeds. The principal modification occurred in the technology required for the suspension system which would permit a comfortable ride during high speed operation especially on curves. In addition, the train was designed to be lightweight, to have a low centre of gravity, and to achieve the objective of speed, reduced

wear and tear on rails and low energy consumption.

Rail speed can be achieved by developing the right-of-way, the roadbed, the signalling system and the locomotive and rolling stock. For example, using a dedicated right-of-way with only fast passenger trains, no grade crossings, and an electronic computerized command and control system can be equally as important as developing new locomotives and coaches. When the LRC project was planned, it was assumed that the infrastructure would not be changed, and that the design changes would be confined to the locomotive and the carriages. In order to obtain further improvements in speed, such as can be achieved with a dedicated right-of-way, other types of design changes would have to be made.

The LRC project was undertaken subsequent to the work which had been done on the Turbotrain in the 1960s. There were three principal firms in the LRC consortium, Alcan, Dominion Foundries and Steel Corporation (Dofasco), and Montreal Locomotive Works (MLW). During the project, MLW was acquired by Bombardier. Two of the original firms, Alcan and MLW, had worked on the Turbotrain, and all three firms had had experience with transport-related projects.

The federal government played a key role in the LRC project. It provided funding for design development and testing, through the Department of Industry, Trade and Commerce (DITC) and the Transportation Development Centre of Transport Canada; and it has provided funding for VIA Rail Canada to purchase ten LRC train sets. Transport Canada has provided subsidies which have permitted the continuation of passenger rail service through the operation of VIA Rail. In Canada, the demand for passenger rail

service declined during the late 1960s and 1970s, and the service was operated at a loss. Continuation of passenger service will require several hundreds of millions of dollars a year to cover the shortfalls between costs and revenues. Any substantial sales of LRC trains would have to come mainly from exports, so that both the demand for passenger rail service abroad and the existence of competing products are relevant in assessing the possible long run benefits to be derived from the LRC project.

An Intermediate Capacity Transit System (ICTS) is an urban rapid transit system intended to fill the gap between the carrying capacity of a bus and a subway system. In the early 1970s two related developments were taking place. The federal government was funding work on an ICTS through the Transportation Development Agency of the Department of Transport, and the Ontario government was supporting similar work in the province.

The Ontario-supported ICTS consists of electrically powered steel wheel on rail light trains, which can run at grade level, on elevated guideways or underground. Trains can vary from two to six vehicles depending on passenger loadings. An automatic train control system allows trains to run as close as 60 seconds apart depending on service requirements. Stations can be integrated with surrounding architecture. This system is designed to meet market situations where the demand is for urban rapid transit up to 25,000 passengers per hour.

By 1981, the City of Vancouver had contracted with a provincially owned corporation in Ontario, the UTDC, to install an ICTS. The process of innovation which led

to this contract started a decade earlier in Eastern Canada, and over the ensuing years involved all three levels of government, federal, provincial and municipal, as well as numerous firms in the private sector. In addition, individuals played key roles in the development process, and because of the nature of their involvement, their perception of what happened, and more especially why it happened, often differs. The project evolved over a period of time, in which a major setback occurred when 'maglev' technology was found to be unsuitable for urban transportation purposes in Ontario. The extended time period resulted in different firms being involved at different stages of the process, so that contracting arrangements were complicated, as was the transfer of cumulative technological know-how which requires the interaction of personnel.

The facts provide a particularly interesting case study of the process of innovation in a sector where government is the customer, government provides the initial funding and bears the risks, and privately owned firms perform much of the work, at least at the outset. The complex contracting arrangements within governments, between governments, and between governments and private firms raise the question of how the decision-makers can be made accountable to the tax-payer for the funds actually spent. Canadian governments, like those in other industrialised countries, provide support for research and development through various policy measures. There have been notable successes, as well as failures. In the field of urban transportation, it is important to understand what the issues are, and how research and development can be promoted successfully in this industry.

FOOTNOTES TO CHAPTER 3

1. The Transportation Development Centre (TDC) was originally called the Transportation Development Agency (TDA). Both names are referred to in this paper.

2. Discussion Paper, op.cit., p. 3.

3. F.M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally, 1970), p. 350.

4. Ibid., p. 350.

5. Ibid., p. 350.

6. Surveys of the literature can be found in: M.K. Kamien and N.L. Schwartz, "Market Structure and Innovation: A Survey", Journal of Economic Literature, Vol. XIII, No. 1, March 1975, pp. 1-37; R.R. Nelson, "Research on Productivity Growth and Differences", Journal of Economic Literature, Vol. XIX, No. 3, Sept. 1981, pp. 1029-1064; and F.M. Scherer, Industrial Market Structure and Economic Performance, 2nd Ed. (Chicago: Rand McNally, 1980), pp. 407-438.

7. Scherer, "The Aerospace Industry", op.cit., p. 335. The emphasis given to"an extraordinarily rapid pace of technological advance" in the quotation is less relevant than the remainder of comments.

8. Discussion Paper, op.cit., p. 7.

CHAPTER 4

CASE STUDY - THE LIGHT RAPID AND COMFORTABLE TRAIN (LRC)

This case study of the LRC train provides a chronology of the project, and a discussion of the technology and firms involved, the assistance provided by government, and the market conditions for passenger train service. Reference will first be made to the Turbotrain project. The LRC project extends over the period since 1967 with the story yet unfinished. The project can be separated into three stages: (1) development of concept, design and construction of prototype; (2) testing and evaluation of prototype; and (3) commercial development and sale of initial train sets. These three stages correspond approximately to the following time periods: 1967-1972, 1972-1978, and 1978 to the present.

THE TURBOTRAIN

The LRC project was undertaken in Canada against a technical background which included the development of the Turbotrain and a demand for passenger rail service which was shrinking. The National Transportation Act of 1967 had effectively brought the development of passenger rail activities to a halt through the 80/20 sharing of the deficit between government and the railways.

The Turbotrain had been developed in the 1960s on the initiative of the United Aircraft Corporation in the U.S. (UAC). The objective of the Turbotrain was to achieve high speed intercity surface transportation in a newly designed train, which would use Pratt & Whitney (a subsidiary of UAC) gas turbine engines. The design involved an attempt to adapt aircraft technology to railways. The Turbotrain was introduced into operation first

in the U.S. between Boston and New York and subsequently for use in Canada. The designer, the Sikorvsky Division of UAC, had had little experience with rail transportation projects, and the use of gas turbine engines as motive power was a fairly new development in North America, although they had been used successfully in France.

United Aircraft of Canada Ltd. (UACL), a subsidiary of United Aircraft Corporation (UAC) in the U.S., arranged construction of the Turbotrain in Canada. MLW, Alcan and Dofasco were three of the principal firms involved in the project. MLW's responsibility was to build the train to the UAC design. This permitted MLW to observe at first hand the problems associated with the design approach involving aircraft technology, and to incorporate this experience in the development of the LRC train which was to use proven ground transportation technology

The Turbotrain experienced difficulties as soon as it was introduced into CNR service between Montreal and Toronto in 1968. At various times the train caught on fire, became frozen, was derailed and became involved in a collision at a grade crossing. An outline of some of the events surrounding the Turbotrain is contained in Exhibit 1.

An historical review of the decisions related to the Canadian Turbotrain project was made in 1975.[1] This review is suggestive of what went wrong and more importantly why things went wrong. The findings include the following:

1. There was overoptimistic enthusiasm by the participants leading to substantial overestimates of

EXHIBIT 1

DEVELOPMENT OF THE TURBOTRAIN - A CHRONOLOGY

1964 CNR prepares specifications for an improved train to service the Montreal-Toronto run.

1965 United Aircraft Corporation in the U.S. approaches CNR with a design proposal for a passenger train more advanced than that envisaged originally by CNR. CNR places an order for the lease of 5 seven-car 125 m.p.h. train sets with the Canadian subsidiary of United Aircraft Corporation.

1966 Construction begins on the train sets.

1968 CNR introduces the Turbo train on the Montreal-Toronto run to operate at 95 m.p.h. Service is discontinued after one month.

1970 Service resumes in May and is terminated eight months later.

1972 CNR signs a lease for three (nine car) trains made up from the original five (seven car) trains. CNR assumed responsibility for maintenance.

1973 Test run is made in January. Service is resumed in June and cancelled after four days. Service is again resumed in December and one train runs each day from Montreal to Toronto and Toronto to Montreal.

SOURCE: J. Lukawiewicz, The Railway Game, (Toronto: McClelland & Stewart, 1976), pp. 151-154.

the net beneficial effects (revenues less costs) of the project. Within a period of one month in 1965, estimates of these net effects were increased from $22.5 million to $77.6 million.

2. The design of the train required it to be operated as a unit so that if one part failed the whole train was out of action. This feature affected both operating and maintenance costs. UACL, which had little experience with the operational aspects of trains, grossly underestimated the running and maintenance costs. CNR officials were aware of both of these conditions in agreeing to the contract.

3. UACL decided not to build a prototype train and test it, but to build five train sets at once. There was thus no chance to experiment with the prototype. CNR encouraged this in part because of the political pressure to have the trains in operation by Expo 67. This delivery date was not met.

4. There was restricted cooperation between the engineering and technical staffs of CNR and the Sikorvsky division of UAC, partly as a result of management decision and partly because of differing backgrounds. The CNR personnel were railway oriented, while the UAC personnel were viewed as being 'space-age Ph.D.s'.

5. Inside CNR, amongst the senior management, there were strong differences of opinion as to the desirability of engaging in the project. The

passenger rail marketing personnel strongly backed the project while the technical, operational and maintenance staff opposed it.

As might be expected, the Canadian participants in the Turbotrain experience take issue with the findings of this study. In particular, CNR contends that there was cooperation with the engineers in UAC, but that it would have preferred developing one as opposed to five trains at the outset.

CNR was conditioned by its experiences with the Turbotrain. It tended to reinforce the belief that before any new train was acquired there would have to be extensive testing. As the principal customer, CNR was involved with the Turbotrain from 1964, gave encouragement to the companies to proceed with the project, and assisted in its development. Despite this experience, CNR also encouraged the undertaking of the LRC project, although its input may have extended the time required to complete the project.

The Turbotrain experience is important in understanding the LRC project and the process of innovation in railways for a number of reasons. First, the Turbotrain illustrates some of the problems associated with attempts made by firms to adapt aircraft design expertise to ground transportation in general, and railways in particular. Second, the nature of the involvement of the customer, namely the railways, in the project can affect the outcome. And third, there was government involvement in at least four ways, as an owner of a passenger railway, as a regulator of the provision of passenger service, as a subsidizer of passenger rail service, and

as provider of incentives for industrial and transportation development.

One basic difference between the Turbotrain and the LRC train was that designers of the latter assumed at the outset that the train would rely on traditional railway technology to develop equipment to be used on existing roadbeds. Aircraft technology was not to be used and solutions were to be found with low technical risk. Thus, the LRC train adapted a diesel-electric propulsion system instead of the gas turbine engine used in the Turbotrain. North American railways replaced steam locomotives with diesel-electric engines in the 1950s, and nad become thoroughly familiar with operating and maintaining such systems. Gas turbine engines were not in widespread use by railways, and lack of familiarity with them would create operational problems if maintenance were to be performed by the railways.

STAGE I, 1967-1972, CONCEPT AND PROTOTYPE DEVELOPMENT

The early stages of the development of the LRC train took place in 1966 with discussions between an engineer in the Product Development Division of Alcan and executives of CNR. In January 1967, Alcan and CNR decided to approach MLW and Dofasco with a view to forming a consortium to develop the train. During 1967, the concept was further developed by Alcan, a brochure was published, and a presentation made to the passenger rail executives of CNR. In December 1967, a presentation was made by Alcan and CNR to Transport Canada, and in January 1968 a presentation was made to DITC for funding from the Program for the Advancement of Industrial Technology (PAIT).

Some preliminary work on high speed passenger trains had been done by Alcan's research organization in Banbury,

U.K., as early as 1948. While Alcan took the lead in drawing up the proposal for the consortium, the member companies had had previous associations on transportation projects. Alcan had been a supplier of aluminum to the Turbotrain, and to MLW for the initial 36 metro cars sold to the Toronto Transit Commission. In addition, Alcan had designed and supplied aluminum for freight cars, for the Tempo Cars built by Hawker Siddeley for CNR, and for equipment used by the Roberval and Saguenay Railway, a subsidiary of Alcan. MLW, Dofasco and Alcan had bid on projects for the Montreal subway, and Alcan had bid to work on a rail link between Mirabel and Montreal. Prior to the LRC train, Alcan's passenger transportation design experience had been mainly for subway vehicles.

Dofasco's previous experience included the design and supply of trucks for CN's Tempo Train, the Toronto Transit Commission, GO Transit, and a number of locomotive trucks. The company had been a major supplier of freight trucks and couplers for many years, and had acquired expertise in this area as a way of developing a market for its steel-making operations.

Technology and Design

In order to understand the development which took place the nature of railway equipment and infrastructure need to be understood. In North America, a very high proportion of railway traffic is freight and a very low proportion passenger, while in Western Europe the reverse is the case. Freight traffic causes much more rapid deterioration of the track than do the lighter passenger coaches, and the railbed requirements for slow moving freight are quite different from those for fast passenger

traffic. In particular, fast trains need to have curves banked in order to avoid the need to slow down and accelerate, and the banking requirements for freight traffic are inappropriate for fast passenger trains. The mix of freight and passenger traffic or the absence of a dedicated right of way for passenger traffic creates design problems for equipment.

A number of adjustments are possible to the vehicles if the track cannot be altered. These include steerable trucks and tilting suspension systems. The steerable trucks allow the wheels to follow the tracks without making flange contact thus avoiding wheel and rail wear and creating a smoother and quieter ride. This feature is not required for high speed trains using specially constructed dedicated tracks which have "high standards of alignment and small curvature". For example, the equipment used on the New Tokaido Line in Japan, a dedicated line, does not use steerable trucks.

A second adjustment is a tilting suspension system which allows the vehicles to bank on curves. There are two types of system in use, a passive and an active system. The passive system permits the coach to tilt as a result of lateral forces which come into play as the train enters the curve. One passive system, which involves a pendulum effect, was used in the Turbotrain. An active system is one where the tilt is activated by a powered system, which causes the coach to tilt at an appropriate time. The Advanced Passenger Train in the U.K. uses an active tilting mechanism and a non-steerable truck, although there is some allowance for movement of the axles around curves.

CNR was approached to fund the LRC project but had declined. Subsequently, the consortium's application for PAIT funding was approved in 1969 for the sum of $1.24 million; this represented 50 per cent of the estimated cost of the project. The funds were to be used for the design and construction of a prototype locomotive and coach which would meet the following conditions: a top speed of 200 km per hour, an ability to achieve a high average speed, an improved standard of ride comfort, compatibility with existing operating and maintenance procedures, and low direct operating cost.

Alcan had the responsibility for designing the coach, supplying the structural aluminum, and performing the structural testing. Dofasco was responsible for the design and construction of the trucks both for the coach and for the locomotive, and for the associated banking servo systems. MLW had responsibility for the locomotive, and the detailed engineering and construction of the coach. The consortium used the Montreal firm of Jacques Guillon and Associates, to act as design consultants for the locomotive and coach, and to build a model of the train, and CNR to perform some development testing at its Technical Research Centre.

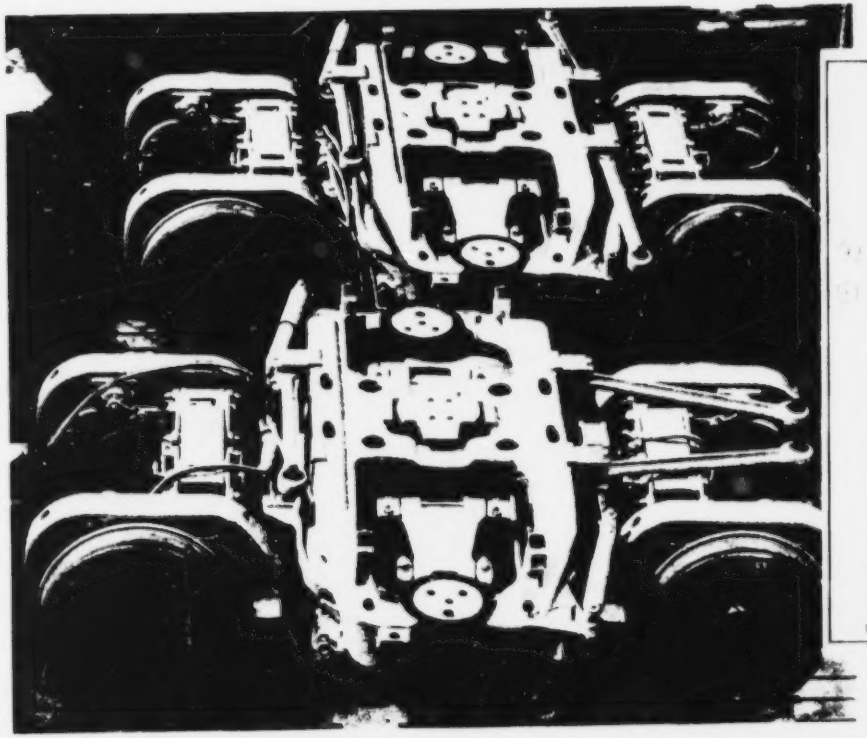
The technology employed in the LRC train has been described as evolutionary rather than revolutionary, "it is intended to suit, with minimum of disruption, the railway operating environment in North America".[2] The main new technical development is in the design of the coach banking or tilting mechanism to the suspension system of the trucks. Dofasco considered numerous mechanisms by which a coach body could be tilted. These included special designs of metal-elastic pads, and rollers

running on a circular guideway in the truck. Ultimately it was decided to proceed with a linkage arrangement which provided a desirable motion and was less costly to manufacture and maintain.

All of the tilting devices considered required a power and control mechanism to provide the tilting movement. Only active tilting mechanisms were considered by Dofasco, since one aim of the design was to use a roll center at the height of the passengers. This approach allowed a greater tilt angle with less sensation of tilting by the passenger, and less lateral swing than occurs with a passive tilting system as in the Turbotrain. The Vickers Division of Sperry Rand Canada and SPAR Aerospace were originally contracted to design and build the power and control systems respectively.

The trucks consist of two parts, the structure and suspension built by Dofasco and the control mechanism to tilt the coaches - see Exhibit 2. A hydraulic system causes the coaches to tilt. This system is activated by an accelerometer on each coach truck which measures the lateral acceleration as the train goes around a curve. This reading transmits a signal to the tilting mechanism of the truck which operates a hydraulic servo-valve causing fluid to actuate a cylinder and tilt the coach.

> The accelerometer signal operates a hydraulic servo-valve which admits high pressure hydraulic fluid to the actuating cylinder and tilts the bolster. The resultant position change reduces the apparent lateral acceleration perceived by the accelerometer. Tilting stops when the difference between the components of gravity and lateral acceleration in the plant of the tilt-bolster falls below the detection threshold of the accelerometer.[3]



1	FRAME	11	VERTICAL DAMPERS
2	DISC BRAKES	12	LATERAL DAMPERS
3	CHEVRON SPRINGS	13	SPRING PLANK
4	ROTARY DAMPERS	14	TRACTION BARS
5	AXLE	15	TRANSVERSE LOCATING LINK
6	WHEEL	16	BEARING PADS
7	TILTING BOLSTER	17	CENTRE POST
8	HYDRAULIC CYLINDER	18	TRACTION RODS
9	AIR SPRING	19	ACCELEROMETER
10	SWING LINKAGE	20	PREVENTER

EXHIBIT 1
TRUCK DESIGN FOR LRC TRAIN

SOURCE: J.E. Tomaka, op.cit., p. 6.

This system tilts the coaches as they enter curves, thus counteracting the unsettling effects of centrifugal force. It allows the train to maintain constant high speeds and provide passengers with a comfortable ride. The passengers feel that the train is travelling on a straight and level track.

The locomotive and coaches are designed to reduce air resistance, by the locomotive having a rounded nose and the coaches having a smooth skin and fully cowled undersides. In order to conform to North American railway interchange standards, the coaches must withstand a compression force of 800,000 lbs. without permanent deformation. This requirement is greatly in excess of European standards (250,000 to 400,000 lbs.) which means that the train is over-designed for European markets. The coaches have a considerable amount of acoustic insulation so that noise levels are not uncomfortable. The weight of a coach is about 105,000 lbs. empty in comparison with standard coaches (Amfleet) of 115,000 lbs. empty.

The prototype locomotive weighed 236,000 lbs. which is about 14,000 lbs. less than a standard diesel-electric locomotive. The final locomotive weights 245,000 lbs., almost as much as standard locomotives. The engine is an MLW Alco series 251, 12-cylinder four stroke turbocharged diesel rated at 3300 hp.

The three elements, Light, Rapid and Comfortable, influenced the technology requirements in terms of the vehicle structure, the propulsion system and the suspension system. The 'light' of the LRC meant that the superstructure of the coaches had to be designed to

permit weight savings which would in turn permit energy savings, affect the type of propulsion systems required, and contribute to the 'rapid' element of the train. In order for the train to be 'rapid' on the existing roadbed, a new suspension system had to be designed to permit high speed operation on curves. Discomfort on curves and over existing trackage would have been experienced using conventional suspension systems. The 'comfort' was mainly associated with the suspension system, although the design of the carriages also contributed to the passengers' comfort.

Prototype Development

The estimated cost of the project, $2.48 million at the time of PAIT funding in 1969 was exceeded by $77,000 and was paid for by the companies. In 1971, the first coach had been assembled and testing began. By the summer of 1972, the prototype had been tested in service over 5,000 miles and the locomotive was 85 percent complete.

The coach performed reasonably well during the testing but there were unexpected problems. Both SPAR Aerospace and McMaster University had undertaken mathematical analysis of banking performance and dynamic stability respectively. To resolve the problems these studies were extended and several hardware changes implemented. At about the same time, CNR financial executives became concerned about the cost of purchasing new trains, and the consortium felt that CNR did not provide the encouragement which had earlier come from the passenger rail executives. This was due primarily to increasing deficits being faced by CNR as the federal government was not allowing the abandonment of unprofitable passenger services.

CNR engineers also expressed a preference for an electrically actuated tilt system, instead of a hydraulic one, since their maintenance crews were not experienced with hydraulic systems. Dofasco felt that such a change was impractical. The overall result was that CNR became less enthusiastic about the project, and delayed any decisions to purchase the train by requesting that more and more tests be undertaken.

In view of the budget overrun, the consortium was faced with the need to raise additional funds. The market prospects for the LRC train in Canada were influenced at this time by the attitude of railways to the continuation of passenger service. In 1967, the Canadian government had passed the National Transportation Act which required a hearing to be conducted before any passenger rail service was abandoned.[4] At the same time the government agreed to pay up to 80 percent of any losses incurr by the railways in connection with passenger service. In 1969, both CNR and CPR had applied for permission to abandon passenger railway service altogether in Canada, a request which was rejected. Passenger service continued, but at a substantial loss to both railroads, part of which was offset by the subsidies. This was the situation in 1971-72, when CNR was also experiencing continuing problems with the Turbotrain.

STAGE II - 1972 to 1978 - TESTING AND EVALUATION

The PAIT funding ended in the spring of 1972, at which time a meeting was held consisting of government officials from the Department of Industry, Trade and Commerce, the Canadian Transportation Commission, the Transportation Development Agency (TDA), and company representatives from CNR, MLW-Bombardier, Dofasco and

Alcan. A decision had to be taken as to whether the project was to continue past the prototype stage and, if so, how the funding was to be arranged. There was considerable discussion as to the prospect for railway passenger travel in Canada and worldwide, and as to who would take the initiative. Eventually TDA agreed to provide support for the next stage, namely the LRC Train Testing and Evaluation Program (TEP).

The involvement of TDA took place because it would have been difficult to obtain further PAIT funding at a time when there was no definite market for the train either in Canada or abroad. TDA's mandate permitted it to take a longer term view and to provide the necessary funding.

The LRC consortium forwarded a proposal to TDA for the TEP in May 1973 for an estimated cost of $460,000. TDA undertook to fund the project on behalf of Transport Canada in the belief that to do so was in the long-term interest of the Government of Canada, the railways and the railway supply industry. DITC supported this view. It was noted that government policy which was providing an 80 percent subsidy to rail companies declaring a deficit in passenger service, resulted in there being little incentive for the companies to invest in new equipment. However, if passenger service was improved, it was contended that the subsidy would be reduced, and that this would lead to a return on the funding for TEP. The Treasury Board approved TDA's submission for funding of $460,000 in July 1973.

CN Technical Research, which was involved in the first coach tests in 1971, was again a participant at

this stage of the project because of the expertise and facilities available at its Technical Centre, and because of the use which could be made of its rail network. CNR agreed to participate but assigned the work low priority. Senior management in CNR had not yet decided on their passenger rail policy, and while their engineers cooperated with the consortium, there was no feeling that the railway was committed to use the equipment. CNR delayed their purchasing decision by requiring ever increasing standards of performance, so that the rolling stock was subjected to much more extensive tests than was usual before a railway would consider making a purchase. This attitude of CNR caused the engineering personnel within the consortium to enter the next stage reluctantly.

The Four Phase Program

The purpose of the TDA funding was to achieve the following objectives:

Technical - the development of data to guide the engineering work to the completion of train development.

Financial and Management - the maintenance of interest and commitment by senior management of the member firms of the consortium.

Sales - the promotion of sales by making the testing and evaluation program a highly visible project: CNR required the equipment to undergo endurance tests in daily revenue service before making any purchases.

The Testing and Evaluation Program consisted of four phases, each of which had a stated objective:

Phase 1: To demonstrate the acceptability of the

LRC to operate at conventional speeds on Canadian mainline track by April 1974.

Phase 2: To explore the full operating limits of the prototype LRC equipment under controlled conditions by July 1974.

Phase 3: To subject the prototype LRC equipment to daily revenue operation over an extended period by March 1975.

Phase 4: To demonstrate the acceptability of the LRC to operate in excess of conventional speed limits on Canadian mainline track and up to 200 km/hr by December 1975.

The original funding for the TEP of $460,000 was increased to $1,066,144 in November 1975. The management and monitoring of the project was proposed as per A, and was agreed as per B in Exhibit 3. A steering committee with membership from TDA, DITC, the consortium and CNR was established, and was chaired by a TDA representative to direct the project. The project manager was an official of MLW-Bombardier who was in charge of coordinating the work of MLW-Bombardier, Alcan, Dofasco and the testing work at CNR.

There was a delay of several months in completing Phase 1 of the TEP for a variety of reasons: a railway strike, lack of agreement on acceptance criteria, lack of a full-time LRC project manager, and a general feeling on the part of the consortium and CNR that there was little urgency for the project, due to the absence of a known strong demand for the equipment. Delay was also caused by wage settlements, and the time taken to obtain approval for and modification to the proposal.

EXHIBIT 3

PROJECT MANAGEMENT

A. Per Treasury Board Submission (June 1973)

TDA provides secretary and liaison with MOT

Project Steering Group Chair: MLW

Management and Monitoring

Project Director

Direct

MLW Alcan Dofasco CNR Res.

B. Per Contract Agreement Prepared (August 1973)

Steering Committee Chair: TDA

Direct

Project Manager by MLW

Manage

MLW Alcan Dofasco CNR Res.

The slow progress at Phase 1 and the lack of consensus as to how the subsequent stages could be expedited led TDA to investigate the possibility of using the U.S. railway test facility at Pueblo, Colorado, as an alternative to the test facilities of CNR. Contact was made concerning the Pueblo facilities in January 1974, but at the time they were not ready to accept customers, and the consortium was not convinced of the need for tests in the U.S. However, later in 1974, the MLW-Bombardier marketing group learned that the U.S. Department of Transport was evaluating foreign passenger rail equipment for possible use in AMTRAK service. Two train sets of the French RTG Turboliner had been obtained by AMTRAK for a two-year evaluation. In addition, seven sets of a modified design were to be built under license by Rohr Industries in the U.S. The U.S. Department of Transport was known to be anxious to evaluate other equipment, such as the LRC, before any further commitments were made regarding the French Turboliner. Thus, undertaking Phase 2 of the TEP in the U.S. was viewed as being particularly attractive to the LRC consortium for marketing reasons.

Arrangements were made to perform the tests in Colorado over a six week period ending in November 1974.[5] The tests covered 35,000 km at speeds which at times exceeded the design limit of 200 km per hour. During the trip to and from Pueblo, some 40 different crews operated the equipment without significant difficulty. The tests showed the equipment to be reliable and were considered a success for the LRC consortium. Some modifications were made to the equipment during the test period, and minor criticisms about cold and noise level in the locomotive cab were made by the operating crews. One

difficulty arose in returning the equipment to Canada after the test, because AMTRAK refused to take responsibility for moving the train, and the consortium had to find alternative insurance indemnity arrangements for the transit of the train. The process of dealing with individual American railroads also created administrative problems.

Phase 3 of the TEP, the testing of the equipment in daily revenue operation, was undertaken by its use in the CNR Tempo Service between Toronto and Sarnia over a nine-month period. The LRC locomotive and coach were tested over 100,000 km for the locomotive and 80,000 km for the coach, and the results were again considered a success for the equipment.

The final Phase 4 of the TEP required testing at high speed operation on Canadian mainline track. Speeds in excess of 200 km per hour had been achieved at Pueblo, and now, on a stretch of CPR track near Farnham, Quebec, a speed of 208 km per hour (129 mph) was reached. At this point, in March 1976, the final testing of the LRC train had been completed. The Department of Industry, Trade and Commerce provided some funding for Stage 4.

The total cost to TDC was $1.1 million broken down as follows:

	$'000
Phases 1, 2 and 3	924
Pueblo, Colorado Testing	60
Pueblo to Montreal and winter operation	91
Other	47
	$1,121

The total cost of the TEP was $1,375,000, so that TDC provided over 80 percent of the funding and the companies supplied the balance.

STAGE 3 - 1978-1981 - COMMERCIAL DEVELOPMENT AND SALES

In January 1977, an order was received from AMTRAK for the lease of two trains, and a $10 million lease-purchase agreement was signed in 1978. Under the agreement, AMTRAK would lease the trains for one year with an option to renew the lease for a second year after which AMTRAK would buy or return the trains. If the trains were returned, Bombardier had an agreement with the Canadian government such that if Bombardier could not sell them, the government would purchase them at a depreciated value not exceeding $9 million. At any time within the first two years, there was an agreed price at which AMTRAK could purchase the trains outright.

The Canadian government gave approval in principle to purchase LRC trains in 1975. An order was made for ten train sets in 1978 after the government had announced its new passenger rail policy which included the formation of VIA Rail. The government's purchase was made on the grounds that it was necessary to demonstrate the equipment in order to show its economic viability, that passenger rail service would become more attractive, and that experience would be gained in operating the equipment. In order to bridge the gap between successful prototype operation and widespread commercial acceptance or diffusion, it was argued that government support was necessary.

The AMTRAK train sets were delivered in late 1980 and the Canadian sets in the fall of 1981. The order for the ten Canadian train sets amounted to $90 million,

of which $60 million will accrue to Bombardier and the remainder to Alcan, Dofasco and Canadian General Electric. The sales are estimated by Bombardier to generate 1500 person years of work for the consortium.

AMTRAK has decided not to exercise their option to lease the two train sets for a second year. Thus, these two sets will be returned to Canada. The ten Canadian train sets encountered problems on being brought into service in 1981 and were withdrawn from service at various times. They were reintroduced later in 1982. Negotiations are underway for the purchase of another ten train sets by VIA Rail.

Over the next decade, it is estimated that if the LRC trains are successful in everyday operation, another 30 diesel-electric LRC train sets, and possibly an electric version of the LRC could be sold in the U.S. market. Other possible markets are considered to be developing countries in Africa, South America and the Middle East. One estimate of the potential market is 80 train sets beyond those already ordered for total sales of about $500,000,000.[6]

The only major U.S. competing firm in the market is the Budd Corporation in which Thyssen Steel of West Germany has a majority interest. Budd builds coaches as well as self-propelled rail diesel cars. Another U.S. competitor, the Pullman Corporation, has withdrawn from the rail equipment business.

Bombardier claims that the LRC train is competitive with plane, automobile, conventional train and bus in

terms of travel time, per passenger cost, and fuel consumption. A Bombardier advertisement makes the following comparison between travel modes:

	Travel time for 335 miles	Per Passenger cost for 335 miles	Fuel Consumption per 1,000 seat miles
	Hours	$	Gallons U.S.
Plane	3.0	68.00	27.8
Automobile	6.0	110.50	51.6
Conventional Train	5.1	23.25	9.6
Bus	6.5	19.15	5.6
LRC	4.0	23.26	4.0

Spinoff Work

The technology developed in conjunction with the LRC has been of value to SPAR Aerospace Ltd. in Toronto which has entered the urban transportation equipment field and has done further work on suspension systems. In addition, the Ontario GO commuter train coaches built by Hawker Siddeley have used a Dofasco truck design very similar to that developed by Dofasco for the LRC train. Subsequent to the work done on the LRC, Dofasco has held three contracts with the UTDC for the development of steerable trucks for use on the newly developed ICTS equipment, which has been purchased by the City of Vancouver. Bombardier has developed a design and manufacturing capability in rail equipment, with spin-offs into the development of a high technology diesel locomotive and the production of heavy rail commuter cars for transit systems in the U.S.

The Market for Rail Passengers

At the time the LRC project was initiated in the late 1960s, the outlook for passenger rail service was not promising for a number of reasons. In 1969, passenger rail miles travelled were about half air passenger miles, partly as a result of a government subsidy per passenger mile, which was substantially higher for air than for rail, and partly because air travel gave better service.

Railway passenger traffic has declined substantially in the post-war period, from 11 billion passenger kilometres (pkm) in 1945, to 5 billion in 1950, to 2.5 billion in 1974, and with a rise to 3.1 billion pkm in 1978. Between 1950 and 1978, the annual use of the rail mode declined from 330 km per capita to 135 km per capita, or almost one half, and now the railways' share of passenger activity is 2 per cent.[7] The railways are principally used for freight, 86 per cent of total revenue in 1978, compared with 4 per cent of revenue from passenger-related services, and 10 per cent from government subsidies under the 1967 National Transportation Act. Passengers mainly use the railways for commuting. About 76 per cent of the travellers carried are commuters and the average commuter journey is 24 km.

The railways claim that they lose money on passenger service. In order to sustain services, the government reimbursed the railways for 80 per cent of the losses up to 1978 in return for a commitment to maintain existing routes, frequencies and price schedules. Since 1978, VIA Rail has assumed 100 per cent of passenger rail operating losses. The level of subsidy reached $384 million in 1978, which was more than double the revenue

of $155 million paid by passengers. The subsidy per passenger kilometre has increased almost 80 per cent in recent years as follows:

	1974	1978	% Change
	----cents---		
Revenue/passenger km	2.75	4.00	+45.5
Cost/passenger km	9.75	16.50	+69.2
Subsidy/passenger km	7.00	12.50	+78.6

Source: Statistics Canada 52-207 (1978).

Prior to the establishment of VIA Rail in 1977, CNR and CPR accounted for about 85 per cent of all passenger rail kilometres travelled and all passenger rail revenues, so that the attitude of these two companies to passenger rail service was vital for any manufacturer who was interested in developing and selling new equipment in Canada in the early 1970s.

The opportunities for innovation lie in the fact that passenger rail service has been provided by obsolescent and aging equipment. The opportunities for passenger rail services are seen to exist in densely travelled corridors where speed can be achieved and the total elapsed time of the journey is reduced relative to travel by bus, car or air. A high speed train operating on a dedicated right of way with no grade crossings and a first class signalling system would enhance the time reliability and attractiveness of rail to passengers. The LRC train involves innovation in part of the system, namely the equipment as opposed to the infrastructure, and can only go part way to increasing the attractiveness of railways to provide passenger service.

FOOTNOTES TO CHAPTER 4

1. P.B. Buchan, The Turbo Train Project, Canadian Institute of Guided Ground Transport Report, No. 75-9 (Kingston, Ontario, 1975).

2. J.Z. Tomaka, "The LRC - A Canadian High Speed Diesel Train", Railway Engineering International, Feb. 1974, pp. 2-10.

3. Ibid., p. 8.

4. This procedure was not adopted in July 1981 when passenger rail service on certain lines was discontinued as a result of an Order-in-Council under Sec. 64(1) of the National Transportation Act. See Minister of Transport, Information Release 130/81, July 27, 1981, p. 3.

5. If the U.S. railways had, at their expense, tested the train, the results would have been made public. TDA's funding of the tests assured confidentiality of the results.

6. On July 27, 1981, the Canadian government announced that VIA Rail's capital budget would expand to allow for up to ten additional LRC train sets for use in Canada.

7. R.F. Webb Corporation Ltd., Post Completion Evaluation of Five TDC Projects (TDC, Montreal, Oct. 1980), p. 63.

CHAPTER 5

CASE STUDY - THE INTERMEDIATE CAPACITY TRANSIT SYSTEM (ICTS)

The process of innovation leading to the ICTS involved two development projects, one sponsored by the Ontario government and one by the federal government. The degree of development has differed between the two projects. Each project will be described separately and relationships between the two noted.

THE PROVINCE OF ONTARIO

1963-1972, Early Development

Prior to 1970, the Ontario government had been extensively involved in the provision of rapid transit systems in Ontario, notably the Toronto subway, Go train and the building of a network of roads and highways. In 1963, the Ontario Municipal Board gave approval to the application by Metropolitan Toronto to construct the Spadina Expressway in Toronto.[1] Expenditure for the expressway would mean a greater use of the automobile as a means of urban transit, instead of alternative modes such as bus, light rail or subway.

On June 3rd, 1971, the premier of Ontario announced the cancellation of the Spadina Expressway project, noting that

> If we are building a transportation system to serve the automobile, the Spadina Expressway would be a good place to start. But if we are building a transportation system to serve people, the Spadina Expressway is a good place to stop.[2]

The government changed its mind on the grounds of the doubling of the estimated costs since 1963, and because of its belief that automobiles should no longer be

encouraged as a mode of urban transportation. Pollution and environmental factors were also considered. At the same time, the government announced that it would cooperate with municipal authorities to develop alternative transportation facilities and would provide "appreciably greater provincial financial assistance for rapid transit services".[3] The government's new urban transportation policy was announced on November 22, 1972. One element of this policy was the development of an ICTS. However, the ICTS proposal originated two years earlier.

In 1970, the Ontario Department of Transportation and Communications (DTC) convened a task force on transportation technology to review the status of development of new transit system concepts and technology.

> On the basis of extensive discussions, literature searches, commissioned studies, and visits of inspection to a number of systems developers in North America and Europe, the intermediate capacity transit system was identified as the primary transit need, as a secondary or feeder system supplementing subways in large urban areas or as a primary system in cities of intermediate size.[4]

The engineering and transportation consulting firms, M.M. Dillon, and De Leuw Cather of Canada were used by the department at this stage.

Because the DTC subsidized road and transit planning, i.e., construction, operation and maintenance in Ontario municipalities, as well as acting in a technical advisory capacity, it was interested in assessing the applicability of new systems in terms of capacity, service and urban environment. Thus, in October 1971, the Premier of Ontario announced that a study would be undertaken

leading to the implementation of a demonstration project of about one mile, connecting Ontario Place and the Canadian National Exhibition in Toronto.

> The primary objective of the study is to evaluate new intermediate capacity transit systems in terms of their technological feasibility, economics (capital and operating) and environmental effects relative to conventional transit systems, across a broad range of capacity and network requirements....On the basis of information already collected, approximately 10 of the most promising systems have been selected for evaluation. The invitation to participate has been sent out only to the selected systems developers.[5]

At this stage, the DTC was headed by the Hon. Charles MacNaughton as minister; Mr. A.T.C. McNab was deputy minister and Mr. Malcolm Armstrong was executive director of research in the department. Mr. Kirk Foley, who later became president of the Urban Transportation Development Corporation, was an employee in the economic analysis branch of DTC. Over the subsequent decade, while the position of minister and deputy minister were filled by different persons, the position of premier was held by the Hon. William Davis.

The Premier's knowledge of and commitment to the position taken regarding urban transportation policy is evidenced by the fact that the premier, not the minister, made many of the key policy statements. It should also be noted that Mr. Malcolm Armstrong, the executive director of research, later became the head of the Federal Transportation Development Agency, which provided financial support for related work on an ICTS, and still later a member of the Canadian Transportation Commission. This digression on the personalities involved is necessary in understanding how and why public funds became

committed to the ICTS project.

The chosen systems developers were invited to a conference on January 13, 1972. Those who accepted the invitation to participate were asked to provide detailed information about their systems by March 17, 1972. The department then would evaluate the submissions and select those systems for inclusion in Phase II by August 1, 1972. These developers would be asked to provide further information by December 1, 1972, after which evaluation would take place and be completed by February 1, 1973.

The first phase of the study requested detailed information on the following characteristics:[6]

A. Functional Requirements

Capacity (4,000 to 20,000 persons per hour per direction)
Operating Speeds

B. System Design Requirements

System expansion
Safety
Fail-safe design
Effect of possible human errors
Back-up devices
Reliability and maintenance
Interior and exterior noise
Electromagnetic interference and susceptibility
Winds, precipitation, temperature

C. Subsystem Design Requirements

Command and control minimum headway
Vehicle
Vibration
Acceleration, Deceleration, Jerk
Emergency Braking

DTC actually invited eight system developers to participate in the first phase (see Exhibit 4), and selected

EXHIBIT 4

EIGHT SYSTEMS CHOSEN BY THE ONTARIO DEPARTMENT OF TRANSPORTATION AND COMMUNICATIONS TO BID ON AN URBAN TRANSPORTATION SYSTEM

System Name	Design Concept	Automatic Command/ Control	Suspension	Propulsion
Alden "StaRRcar" (USA)	PRT	Yes	Rubber tires	Rotary AC motors, hydrostatic drive
Ford "ACT"	Line-haul or PRT	Yes	Rubber tires	Rotary DC motors
Transportation Technology Inc. (USA)	PRT	Yes	Air cushion	Linear induction motors
Uniflo (USA)	PRT	Yes	Air cushion	Linear Air Turbine
Bertin "Aero-train" (France)	Line-haul	Optional	Air cushion	Rotary or linear induction motors
Urba "30/100" (France)	Line-haul	Optional	Negative pressure air cushion	Linear induction motors
Hawker Siddeley Canada (Canada)	Line-haul with off-line stations	Optional	Rubber tires	Linear induction motors
Krauss-Maffei "Transurban" (Germany)	Line-haul or PRT	Yes	Electro-magnetic	Linear induction motors

SOURCE: Ontario Ministry of Transportation and Communications Research and Development Division, Intermediate Capacity Transit-Ontario's Program, Feb. 1974, p. 6.

three to proceed to Phase II, Ford, Hawker Siddeley and Krauss-Maffei. Ford withdrew on the grounds that it was not in their corporate interest to re-design their system to meet Ontario's specifications. The other two firms received payments of $50,000 each to submit technical design proposals and bids, which they did by February 1, 1973, on schedule. These proposals were evaluated and Krauss-Maffei AG of Munich, West Germany was awarded a $16 million contract for the Transit Demonstration System on May 1, 1973. The system was to be in operation prior to the opening of the CNE in 1975.[7]

Thus, the DTC had initiated the ICTS study prior to the premier's announcement on November 22nd, 1972 of the new urban transportation policy for Ontario. The premier summarised the provincial position on transportation policy (Exhibit 5), and outlined a six-point program of new policies (Exhibit 6). Note was taken of the work already done on an ICTS, and one proposal consisted of a provincial commitment to fund a prototype and operating demonstration of an ICTS. In fact, this commitment was already being fulfilled and the study by DTC was evaluating support systems using rubber tires, air cushions and magnetic suspension, as well as linear induction motors and automated control systems. In addition, studies had been conducted of the feasibility of ICTS in Toronto, Ottawa and Hamilton.

1973-1974, A New Direction

The DTC study and the premier's statement were the forerunners of the government's decision to set up a Special Act Company, the Ontario Transportation Development Corporation (OTDC) in June 1973.[8] The OTDC was established to hold and exercise the license rights

EXHIBIT 5

A SUMMARY OF EXISTING TRANSPORTATION POLICIES IN ONTARIO

The province of Ontario is committed to a policy of an integrated approach toward the transportation of people and goods within the province. With that policy in mind, the Government has already done the following:

- Brought together all transportation responsibilities of the Government into one Ministry to permit better planning and coordination.

- Taken steps to coordinate our transportation planning with the municipalities, thus developing a truly provincial integrated network.

- Extended the municipal subsidy for transportation planning. At one time, the subsidy was available for development of roads only. Now it includes all other forms of transit.

- Provided aid to municipal transit systems in the form of deficit subsidies.

- Broadened subway subsidies to include construction, rolling stock and stations.

- Developed, in partnership with municipal authorities, new transit systems and upgraded existing ones.

- Financed demonstration projects in the public transit field.

- Evaluated new modes of transit, particularly the intermediate capacity type.

We are now ready to move into the next phase and to assist, to a greater degree than ever before, in the planning and financing of public transportation systems which will emphasize the comfort and convenience of people in all parts of Ontario.

SOURCE: A Statement by the Hon. William Davis, An Urban Transportation Policy for Ontario, Nov. 22, 1972, p. 20.

EXHIBIT 6

A SUMMARY OF PROPOSED TRANSPORTATION POLICIES IN ONTARIO

The Province will shift emphasis from urban expressways to a variety of transportation facilities, which will put people first. This policy will be implemented through a six-point program:

First, subsidies of 75% for the purchase by municipalities of buses, streetcars and trolley buses, and related facilities;

Second, the development at Provincial expense of a prototype and operating demonstration of a new form of intermediate capacity transit system together with a subsidy program of 75% to assist municipalities in applying the system to meet their needs;

Third, subsidies for programs to alter demand for transportation at peak times such as the encouragement of flexible working hours to spread peak loads in major cities;

Fourth, subsidies of 50% to urban areas for upgrading and expanding computer controlled traffic systems;

Fifth, continuation and expansion of studies in cooperation with municipalities in order to maximize the use of existing roadways through the study of such means as one-way streets, delivery and parking policies;

Sixth, an intensification of Provincial efforts and resources devoted to the coordination of transportation planning among the municipalities in Ontario.

SOURCE: A Statement by the Hon. William Davis, An Urban Transportation Policy for Ontario, Nov. 22, 1972, p. 20.

acquired by the government from Krauss-Maffei. These rights included the following:

- exclusive license rights on all present and future related technology, to include all patents and industrial property associated with the Krauss-Maffei system, for any application in Canada. These license rights include a training and know-how transfer provision to ensure capability of application.

- non-exclusive license rights in Central and South America to ensure an export market for Canadian industry and a "most favoured nation" provision for sales to the balance of the world, except the European Common Market. Special provisions apply to the United States market where the OTDC receives a percentage of all royalty income from that market.

- the right to sublicense companies in Canada for the manufacture and sale of complete transit systems, subsystems, and components.

- a contractual commitment that prior to May 1, 1974, Krauss-Maffei will establish a Canadian controlled company in Canada to hold one such sublicense.

- a contractual commitment for the provision of future technological development by Krauss-Maffei.[9]

The role of OTDC was:

- to coordinate and promote the development of advanced technology of all types relating to public transit and to integrate this development with the design and production of conventional transit facilities.

- to fund research in transit innovations in intermediate capacity systems and others.

- to market systems through the private sector in Ontario and in Canada.[10]

The Canadian government and other provincial governments were invited to take an equity position in the OTDC,

but declined to do so.[11] The Ontario government recognised that urban transit problems were not unique to the province, and that their solution could be undertaken with the assistance of Canadian industry from all parts of the country. This national outlook was recognised explicitly when the corporation's name was changed in October 1974 to the Urban Transportation Development Corporation. However, this did not result in participation by other governments.

A second feature of the corporation was that it should facilitate the generation of industrial benefits by being the institutional mechanism for transferring and holding technology imported from abroad. The premier stated:

> The Transportation Corporation is a catalyst, it has been formed to stimulate, not dominate. It has been formed to coordinate, not control.[12]

The government appointed as the first chairman of the board, Mr. E.R. Rowzee, who was at that time the chairman of Polysar Ltd., a federal Crown corporation, and as president, Mr. Kirk Foley, an employee with DTC.

The president of UTDC explained to the news media that the corporation would have two principal functions, 'product research and development' and 'license, management and marketing'. The term 'marketing' embraced both manufacturing and marketing, but the emphasis was given to marketing or the need to satisfy the customer. As shown in subsequent presentations, the intent of OTDC was to contract out manufacturing to the private sector.[13]

In April 1974, the president of OTDC made a presentation to the Metropolitan Toronto Transportation

Committee and the Toronto Transit Commission in which the progress with the ICTS using Krauss-Maffei technology was described. The project was now called GO-URBAN. The Test/Demonstration System at Exhibition Park, Toronto, was already under construction and testing was due to begin in early 1975.[14] The estimated capital cost of an operational system was $12 to $15 million per mile. Despite the emphasis on Canadian industrial benefits, a number of foreign firms were identified as subcontractors: CEM, a French firm was to supply gramme-ring wound motors; a German manufacturer, Konz, would supply diamond-wound motors, as would SPAR Aerospace of Toronto. The government also provided SPAR with an industrial development grant of over $2 million to work on linear motors. At its Toronto factory, SPAR was building a test track facility to test linear motors at speeds up to 70 mph. The ministry also contracted with ABAM Engineers Inc. of Tacoma Washington to design the elevated guideways.

The principal contractor, Krauss-Maffei, was described as follows:

> The K-M system is unique in that it employs no moving parts for basic suspension, guidance, propulsion and braking. All of these functions are provided by the precise control of electro-magnetic energy without physical contact between vehicle and track.
>
> A manufacturer of locomotives for over 130 years, Krauss-Maffei have developed their concept for urban transportation from this high speed test prototype.
>
> It is suspended and guided by magnetic levitation and propelled by a linear induction motor. It has achieved speeds of 100 mph on its one kilometre test track and it has made thousands of successful runs. From their experience with this vehicle, K-M is developing the low speed urban

system of interest to Ontario.

> Both low speed urban and the high speed variants of the K-M concept are supported and guided by magnetic levitation.[15]

The concept was, however, supported and guided, not only by magnetic levitation, but also by funding from the West German government. During the latter part of 1974, this government decided to withdraw its support, because of the technical difficulties being encountered in translating the experience gained from a one-kilometre test track to operational use in an urban rapid transit setting.[16] The government of Ontario had chosen a system which did not have a proven track record, and which utilised unconventional technology as far as urban transportation was concerned. An announcement was made regarding the technical difficulties encountered in the development, and the government of Ontario, by the end of 1974, decided not to continue its support once the West German government had withdrawn.

As late as September 1974, UTDC announced its involvement with McDonnell Douglas Corporation of St. Louis, through its subsidiary, Douglas Aircraft Corporation of Canada, to cooperate in the development of Krauss-Maffei technology for ICTS. Thus, just weeks before the cancellation, UTDC was extending its commitments to GO-URBAN.[17]

It should be noted here, but will be dealt with in detail in a later section, that the federal government became involved in its own study of an ICTS early in 1974, at a time when the Ontario project appeared to be advancing rapidly. UTDC made a detailed presentation

to TDC in October 1974 in response to TDC's request for proposals for a concept definition of an ICTS. The UTDC consortium of companies bidding on this proposal included SPAR Aerospace, Canada Systems Group, Transurban, Hawker Siddeley Canada Ltd., Douglas Aircraft Company of Canada, as well as OTDC.[18] Thus at the same time that GO-URBAN was cancelled, UTDC saw an opportunity for further funding from the federal government.

1975-1980, Death And Rebirth

The cancellation of the GO-URBAN project forced the corporation, now the Urban Transportation Development Corporation, to come up with another plan. This it did, when on April 14, 1975, the minister of Transportation and Communications authorized the UTDC to proceed with Phases 1 and 2 of a five-phase program to develop an ICTS. The first two phases were completed within the time and cost limits of thirteen months and $6.1 million.

In June 1976, UTDC reported that Phases 1 and 2 have produced:

- an operational requirement document describing the transit needs of Ontario and Canadian municipalities. The requirement for ICTS has been endorsed by the TTC;

- a preliminary design for ICTS which will meet the operational requirements;

- detailed system specifications, program plans schedules and cost estimates on which the government can base a decision to proceed with the Phase 3 Prototype System Development Program. The Phase 3 program which UTDC is recommending will result in government expenditures averaging $15.5 million per year over the next three and a half fiscal years. The objective of Phase 3 is to develop the ICTS to the point where a municipality can make a decision to implement the system.[19]

The report emphasised that the proposed system would meet the needs of large cities which were emphasising decentralized employment centres, and smaller cities which were concentrating employment in central areas. Support for an ICTS was noted from transit system operators, and by comparing ICTS to the much higher capital costs of building subways.

During Phase 2, a preliminary design had been developed which emphasised the key system objectives of low noise, minimum visual impact, and high frequency of operation. The commercial viability of the ICTS was supported by estimates of what it would cost to build alternative transit systems in the Toronto area.

UTDC recommended to the government of Ontario that it proceed with Phase 3 in two stages - 3A, component and subsystem development and 3B, integrated system development and testing at a Transit System Test Facility to be constructed in Ontario and operated by UTDC. Phase 4 would be Production Development and Testing, and Phase 5, Revenue Production.

On the basis of over 150 studies of technical, operational and marketing aspects of an ICTS, at the end of Phase 2, UTDC had defined the operational requirements of the system, Exhibit 7, and had examined the technology options. The major technology selections were as follows: steel wheel on steel rail; track-based switching; linear induction motor and inverter; and supported vehicles.[20] The major development tasks which would be dealt with in Phase 3 would be:

1. To develop a steerable axle truck for the vehicle.

EXHIBIT 7

MAJOR OPERATIONAL REQUIREMENTS FOR ICTS

CAPACITY	Basic - 15,000 passengers/hour/direction Maximum - 20,000 passengers/hour/direction with multiple-guideway stations or longer platforms and trains.
SERVICE CAPACITY	Local Skip-stop Express
STATION HEADWAY BETWEEN TRAINS	Design to permit as low as 50 seconds.
OPERATING SPEED	Maximum 20 m/s (45 mph).
STATIONS	Single and multiple track stations, designed for manned or unmanned operation. Goal for maximum length is 35 metres. Functional and physical links with intersecting transit facilities. Specifications for protection from the elements, for escalators, lighting, suitability for security surveillance and for service to the handicapped where required.
GUIDEWAY	Suitable for elevated guideway and stations in specific situations, and for at-grade and underground application.
VEHICLES AND TRAINS	Minimum consist of two single vehicles, or one articulated vehicle. Capability for coupling and uncoupling under remote control.
AUTOMATED CONTROL	Capability to operate under fullly automatic control. Provision for driver/attendant as an operator option.
EXTERNAL NOISE	Without barriers = 72 dBA. With low barriers = 65 dBA.

Exhibit 7 cont'd.

GRADE	Grade up to 6%.
HORIZONTAL TURNING RADIUS	Minimum 35 metres on main line and station guideway.
SWITCHING	Branching and merging up to maximum operating speed.
COMFORT	The ratio of seats to vehicle practical capacity to be at least 1:3. For the comfort of passengers, the constant jerks to be no more than ±0.13 g and ±0.10 g/sec. Vibration of the vehicle floor will not exceed the comfort level of acceleration more than 5% of the time. Interior noise level will not exceed 65 dBA.
ENVIRONMENTAL CONDITIONS	Specified operational availability in typical North American climatic and electromagnetic environments.
OPERATIONAL RELIABILITY	Specified as maximum frequency of passenger delays and in terms of equipment availability.
SAFETY AND SECURITY	Specified as conditions for "vital" functions and in terms of explicit safety policies.
HOURS OF OPERATION	Operations/Maintenance/Logistics to permit operation at least 20 consecutive hours per day.

SOURCE: ICTS Development Program, Report on Phases 1 and 2 and Recommendations for Phase 3, Vol. 1, pp. 18-19.

2. To ensure the reliability of a linear induction motor.
3. To develop a friction breaking unit and motor brake control logic.
4. To design a new propulsion cooling system.
5. To reduce the external noise level.
6. To develop a vehicle body and auxiliary system.
7. To develop an automatic train control system and an automatic coupler/decoupler system.
8. To design the guideway and stations.
9. To ensure system works under prevailing weather conditions.
10. To develop a system maintenance plan.
11. To undertake system development and testing.

The cost of proceeding with Phase 3 was estimated at $55.5 million over the period 1976 to 1980.

The technical reports supporting UTDC's findings and recommendations were undertaken by Canadian and foreign firms. UTDC prepared 32 reports, including studies of the potential ICTS routes in Toronto, Ottawa and Hamilton. Canadair and its subcontractors were responsible for 65 reports; Rohr Industries Inc. for 29; Standard Elektrik Lorenz, A.G. for 14; and a variety of organizations, but mainly consultants, for the remaining 14 reports.

The development team proposed for Phase 3 included a number of these firms, whose responsibilities are outlined in Exhibit 8. It was still very much the philosophy of UTDC that the technology should be developed as a result of cooperation between public sector venture capital and private sector 'know-how'.[21]

EXHIBIT 8

SUB-CONTRACTORS SELECTED BY ICTS FOR

PHASE 3 OF THE ICTS PROJECT

1. Canadair Limited of Montreal was selected as the System Development Contractor. This company has extensive experience in the development of aerospace and ground-based hardware. Development programs successfully undertaken in recent years include the CL84 Vertical Take-Off and Landing Aircraft, the AN/USD-501 Airborne Drone-Surveillance System for military application, the CL215 Water Bomber aircraft and the XM571 tracked personnel carrier. A Canadair subsidiary, Flextrac-Nodwell is the leading Canadian manufacturer of tracked utility vehicles for off-road use. Canadair has a strong capability to manage development activities of both Canadian and foreign sub-contractors.

2. SPAR Aerospace Products Limited of Toronto was the propulsion sub-contractor. SPAR has wide experience in design, production and marketing of electromechanical and electronic systems for aircraft, space and ground applications. They have established a development team with experience in linear induction motors. SPAR designed and built LIM's for the Krauss Maffei Transurban system. They have subsequently built a major propulsion test facility and track at their Toronto plant.

3. Kilmer Van Nostrand Company Limited of Toronto was the sub-contractor responsible for the guideway subsystem and for design definition of a system test facility. KVN are teamed with ABAM Engineers of Tacoma, Washington, a consulting civil engineering firm pre-eminent in the field of designing elevated structures.

4. H.H. Angus and Associates Limited of Toronto was the sub-contractor responsible for electrical power distribution.

5. Standard Elektrik Lorenz, A.G. of Stuttgart, West Germany was the command control and communications sub-contractor. SEL is a major European supplier of railway signalling and control equipment. They have designed a system of automatic train controls applicable to urban transit systems, which is in an advanced state of development. SEL, an ITT affiliate, will work with ITT Canada to supply command and

Exhibit 8 cont'd.

control hardware and development expertise. It is expected that SEL will assist UTDC to introduce the ICTS into the European market.

6. Rohr Industries Inc. of Chula Vista, California is the vehicle sub-contractor. Rohr has strong innovative design and manufacturing experience in transit vehicles, having built cars for the BART and WMATA systems in San Francisco and Washington. As such, they provide the ICTS team with both technical expertise and the potential to enter the American market.

SOURCE: ICTS Development Program, Report on Phases 1 and 2 and Recommendations for Phase 3 (Appendices), Vol. 2, pp. A31-A32.

Technical Design

The technical ingredients of the prototype system can be separated into propulsion, command and control system, steerable truck, vehicle structure and elevated guideway.

Propulsion System

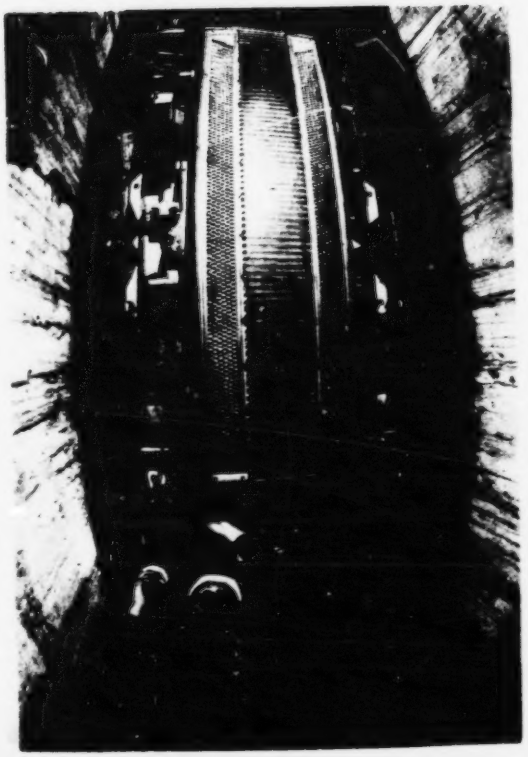
Linear induction motor (LIM) technology was available in Ontario as a result of experience gained from the discontinued maglev programme, and from the team of engineers brought to Canada by SPAR Aerospace after the termination of the Tracked Hovercraft program in the U.K. This technology had been known for around 75 years but the efficiency of LIMs had always been very poor compared with conventional transit rotary motors which drove the wheels directly.

A LIM works on the principal that electricity is used to create a magnetic field such that attractive or repulsive forces of a magnet propel the vehicle along a track. LIMs, unlike rotary electric motors, have no moving parts and thus the problems associated with maintenance and replacement of wearing components are eliminated. Also, LIMs require neither gears nor a transmission system such as a drive shaft, and no wheel slippage occurs as in the case of power being applied directly to the vehicle wheels.

The LIM which was designed for the ICTS consists of two parts, a motor which is situated under the truck of each vehicle, thus two LIMs per vehicle, and a reaction rail situated as a third rail between the two support and guide rails on which the vehicle wheels run. The LIMs attached to the trucks are shown in Exhibit 9 and the reaction rail in Exhibit 10. A LIM operates like

EXHIBIT 9

LINEAR INDUCTION MOTOR



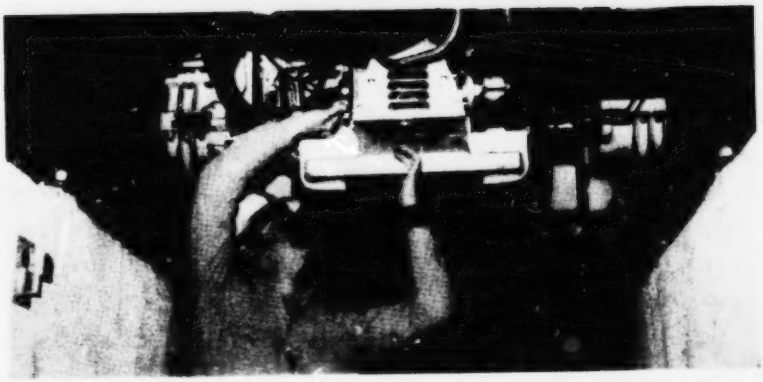


EXHIBIT 10

ICTS - VEHICLE SHOWING TWO SUPPORT RAILS

AND CENTRE REACTION RAIL

a rotary motor which is stretched out flat.[22] Alternating current coursing through the windings induces a complementary current in a parallel metal plate (the reaction rail), but the induced current is not quite in step; it constantly lags behind. As a result, the magnetic fields accompanying each cycle differ in phase. This phase difference produces a repulsive force (longitudinally) between the windings and the reaction rail. The windings therefore produce reaction thrust to pull the train along the flat and up an incline. The process can also be used for braking.

It was found that the LIM would not work effectively with rubber tires, because of the need to keep the LIMs at a set distance, about 15 mm, above the reaction rail. This led to the selection of steel-wheeled trucks operating on steel rails. The trucks then had to be designed to operate at a noise level acceptable to an urban setting.

SPAR Aerospace was originally given the responsibility for developing the LIM using the expertise obtained from the Tracked Hovercraft program. Problems had to be overcome regarding the thrust efficiency of the system, and the motor control system through the development of an inverter. SPAR used a 1400' test track for this development phase, but the problems were only partially solved when SPAR terminated its involvement with the project in 1977. Canadair, the project manager, took over from SPAR and contracted for magnetic analysis work on the LIM to be undertaken by engineers at Bath University in the United Kingdom, where certain LIM expertise resided. Two former employees of SPAR were hired by Canadair to work on the project.

The original inverter used on the LIM was obtained under license from Rohr, but when it was finally found to be unsuitable in 1978, after the SPAR tests, UTDC contracted with GEC in the U.K. for the development of a transistorized inverter. GEC produced a suitable inverter by 1980, and licensed UTDC to produce the inverter worldwide for ground transportation use. This inverter technology has now been transferred to Canada.

SPAR transferred its interests in LIM technology to UTDC, and the production of both the LIM and the inverter will now take place in Canada. These are two of the innovative high technology components of the system. The choice of the propulsion system influenced the design of the guideway, the tracks, the vehicles, and the command and control system.

Command and Control

The Krauss-Maffei maglev system had used an adaptation of a railroad command and control system which had been developed by SEL Germany, a subsidiary of ITT Germany, itself a subsidiary of ITT in the U.S. The SEL system was actually used to control a freight system involving 160 KPH traffic between Hamburg and Bremen. UTDC recognised that the system could be adapted to urban transportation use so that computerized controlled guidance could be provided to vehicles under short headway conditions, i.e., short distances between operating vehicles.

A somewhat technical description of the train control system is as follows:

> Based on the SELTRAC moving block concept of Standard Electric Lorenz (ITT Canada) the system is composed of 3 elements in a hierarchical structure. The System Management Center (SMC) is a single processor which, in conjunction with

> a human operator, carries out supervisory functions such as scheduling, rerouting, system startup/shutdown, emergency procedures, etc. The Vehicle Control Center (VCC) is a triply-redundant processor with responsibility for safe train movement. It communicates with each train via inductive loops laid between the tracks and receives supervisory messages from the SMC which are subject to the safe scrutiny of the VCC. The Vehicle On-Board-Control (VOBC) is a redundant processor which receives and verifies commands from the VCC and produces safe execution commands for propulsion and braking, doors, couplers, etc.
>
> Collision prevention is assured by providing each train with a stopping point that is a safe distance behind the last reported position of the previous train. Three types of control systems are available: 1. automative (described above); 2. cab-signalling; and 3. manual.[23]

The centralised computer communicates with the vehicle via two cables running on the inside of each guide rail. The vehicle picks up the information from two antennas fixed to the underside of each vehicle (see Exhibit 11). Also visible in Exhibit 11 is the power rail (the low fence on the right hand side), which supplies electricity to the LIMs of the moving vehicle through contact pads attached to the vehicles.

The SEL system allows for automatic train control with trains running 60 seconds apart,

> The computers can handle virtually everything from switching to coupling. The system is so efficient that trains can run back-to-back, with no space between trains except that required for safe braking. And when a train enters a station, the computers can stop it within four inches of the right spot.[24]

The SELTRAC technology for urban transportation use

EXHIBIT 11

UTDC - ICTS VEHICLE AND GUIDEWAY COMPONENTS

has been transferred to Canada as a result of the establishment of SEL Canada with a seven-person team undertaking software/design work. The SEL system is now being produced in Canada. Previously, the product mandate for the SELTRAC control system was held by SEL Germany on behalf of ITT. The negotiations with UTDC required permission to transfer the Canadian mandate to SEL Canada. SEL subsequently decided to handle all railway signalling business in North America from the Canadian base.

Steerable Truck

Two of the basic requirements of the ICTS were that it should provide a quiet and comfortable ride. The quality of the ride depends largely on the contact made between the vehicle and the guideway, in this case the steel wheels and the support rails. The truck consists primarily of the four wheels, two axles, and the suspension system for the vehicles.

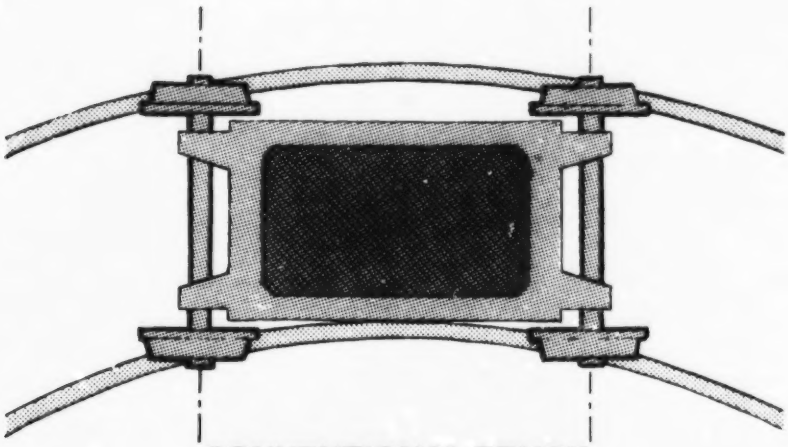
> A truck is a series of trade-offs....Creating the basic layout of wheels, brakes, motors, suspension and so on, and arranging them into an efficient, compact but accessible package, is an art.[25]

In the case of the ICTS, the braking system was part of the LIM, but the truck did have to be designed to reduce the squealing effect caused by the contact of the wheel flanges against the steel rails on curves.

A conventional railroad truck has fixed axles and wheels which cause both squealing and wear of rails. The truck designed for use on the ICTS is a steerable or articulated truck which permits the axles to swivel and allow the wheels to follow the rails through curves (Exhibit 12). The noise level is also reduced

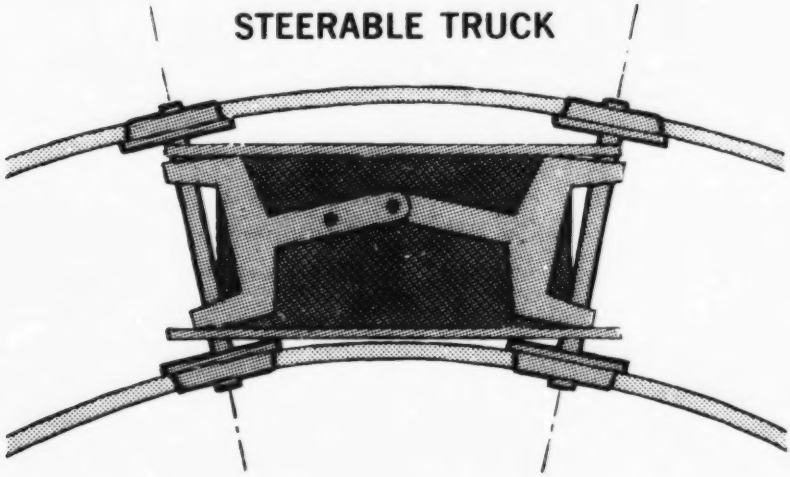
EXHIBIT 12

RAILROAD TRUCKS



CONVENTIONAL TRUCK

STEERABLE TRUCK



by the use of welded rails, the placement of rubber inserts in the wheels to make them resilient, and special wheel designs. The vehicle operates at a noise level of 67 dBa compared to 75 to 90 dBa for other urban transit systems.

A patent on a steerable truck was taken out in the late 1800s, and use was made of this equipment on a Swiss mountain railway between 1935 and 1960. Some production of steerable trucks for freight use is also taking place in South Africa. UTDC acquired two patents on steerable trucks held by Mr. List, a private inventor, in the U.S. Mr. List worked as a consultant to UTDC while it was involved in developing a prototype steerable truck. Later work involved DOFASCO and a second generation steerable truck was developed. This design is now being tested on the ICTS and involves steering the axles by a connection from the body to the truck axles. As a result of this work, a third generation steerable truck has been designed, and has attracted strong interest in the U.K., France and Canada.[26]

Vehicle Structure

Some of the characteristics of a typical ICTS vehicle are as follows:

Length	12.7 m
Width	2.5 m
Height	3.12 m
Weight	1300 kg

	Seated	Standing	Total
Design Capacity	28	55	83
Crush Capacity	28	77	105

Engineers have adapted aircraft technology to design the structural characteristics of the ICTS vehicle body. The structural frame is aluminum as is the thin covering

shell. A patented welding technique allows the skin and structural members to be welded without discoloration or disfiguration of the shell. Due to the simplicity of the overall design and this welding technique, the vehicle structure requires relatively little labour to construct, and the vehicles could be built in countries with low level technological capability. The initial vehicle frames were extruded by Alcan in Kingston which has now bid on the Vancouver contract.

Canadair was originally responsible for vehicle construction and it was active in the project through its ground transportation division, Canadair Service Ltd. However, once its aircraft business picked up with the development of the Challenger, Canadair withdrew from ground transportation development, and the group of about 75 persons (45 engineers plus 30 support staff) working on the ICTS transferred to UTDC. In 1976, UTDC had established a wholly owned subsidiary, Metro-Canada Ltd., to deliver a project to Venezuela. This subsidiary was used to purchase the assets of the ground transportation business of Canadair Services Ltd., itself a wholly owned subsidiary of Canadair Ltd., owned by the federal government.

Other parts of the vehicle consist of fairly standard railroad and transit equipment such as seats, windows, lighting and air conditioning as an optional feature. Swedish couplers, French door-operators and U.S. disc/hydraulic brakes are used, but overall the Canadian content of the system is stated to be about 90 percent.

Elevated Guideway

Elevated transit guideways have been in operation for some years in Paris, Philadelphia and New York, and newer and shorter systems operate in Morganstown, West Virginia and the Dallas-Ft. Worth airport. These installations provided some insights into the design of elevated guideways. UTDC contracted with a U.S. firm of consultants, ABAM Engineers, who had worked on the Disneyworld and Seattle elevated systems. ABAM had expertise in structural analysis of guideways, concrete technology and quality control in high stress concrete.

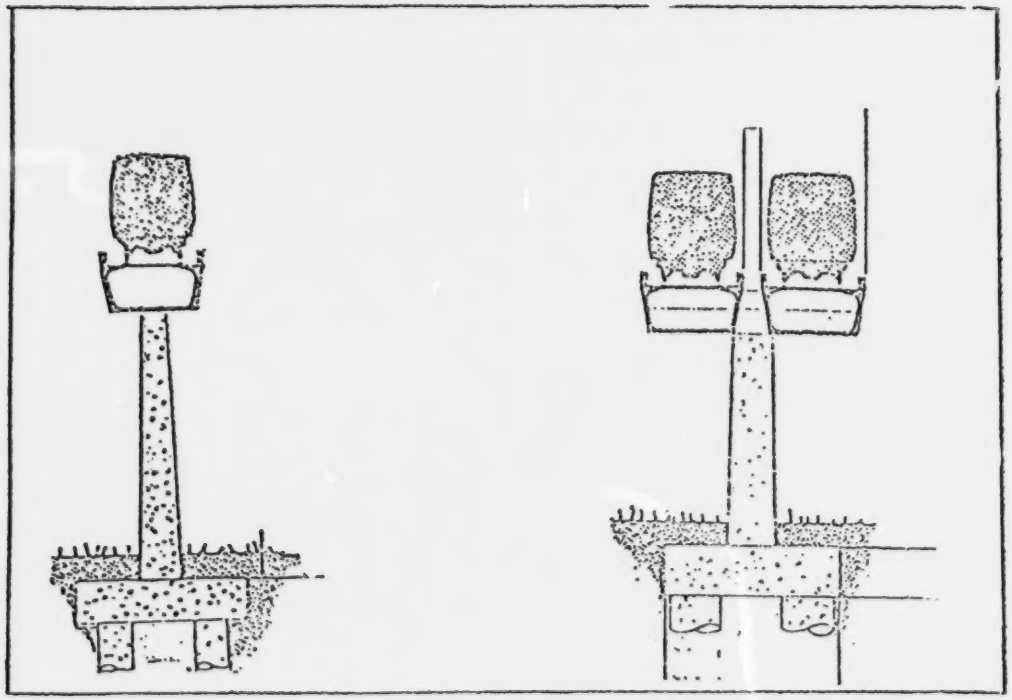
An elevated as opposed to a grade level guideway was chosen on the grounds that an elevated guideway would permit use of a dedicated right of way without grade crossings, and this would be compatible with an automated command and control system. In addition, an elevated guideway is more flexible because it can be inserted into more places, and is easier to protect.

The disadvantages of an elevated guideway are visual, aesthetic and noise intrusion. The noise level was reduced with the design of the truck, and it was decided that visual and aesthetic intrusion could be dealt with by careful architectural design of the guideway and stations, and engineering design of the vehicles.

The elevated guideway is fabricated of precast trapezoidal box beams up to 30 m in length. The beams are typically installed about 6 m above the ground on slender columns spaced about 30 m apart (Exhibit 13). At ground level, a concrete slab about 20 cm thick is used to support the rails and other equipment. The columns are sufficiently narrow to be located in the

EXHIBIT 13

UTDC ELEVATED GUIDEWAY DESIGN



medians of existing highways. The guideways can have either single or dual lanes. The use of standard railway gauge permits normal operation with crosswinds up to 120 kph and ensures stability against overturning in winds up to 150 kph.[27]

Phase 3, Prototype System Development and Testing began in September 1976 followed by Pre-Production Development and Testing. Phase 3 ended on January 31, 1980 by which time $57.2 million had been provided by the Ontario government for total funding of $63 million. Phase 3 included the construction of the 2.6 km test track facility at Kingston, which began operating in September 1978. Also, in 1978, a design study was completed suggesting how an elevated ICTS could be inserted into an urban setting without undesirable environmental impacts.[28]

During the course of the project, UTDC worked with a Technical Advisory Board consisting of transit representatives from Toronto, Chicago, London Transport and Washington Metro. The Board met three times a year to review the progress of the ICTS project and to act as consultants on an honorarium basis.

UTDC now has two wholly owned subsidiaries, Metro-Canada Ltd. and UTDC R&D Ltd. established in March 1981. Total employment is about 400 persons, over 300 of whom are located in Kingston. By 1982, an assembly plant will be built at Kingston for the ICTS, and employment at Kingston will rise to about 500.

The Kingston location consists of 480 acres of which 180 are planned for development into a transit-related

industrial park. An objective of the Ontario government throughout the project has been to generate industrial development in Ontario specifically, and the rest of Canada in general. A major reason for supporting the development work was the high cost of building any further subway systems at an estimated $80 million per double-track mile (1981 costs).

The Market

In 1978, the Ontario government proposed that the federal government participate with it to install an ICTS in Hamilton and Toronto, with UTDC as the prime contractor. Ontario further proposed that the estimated $135 million ($70 million for Hamilton) be funded jointly with each government paying 45 percent and the municipality paying 10 percent. Hamilton-Wentworth Regional Transit Commission and the regional and city councils endorsed the proposal, however, federal participation was delayed by two elections. The project was centered at the Hamilton Rapid Transit Project Office regarding the Hamilton plan, and involves specialists from four levels of government plus industry, consulting firms and UTDC. By January 1980, a federal commitment had not been made and Ontario provided $3.5 million to pay for a pre-implementation work study.

Vancouver, in December 1980, chose UTDC's advanced light rapid transit (ICTS) system to link downtown Vancouver with New Westminster, Surrey and Coquitlam. The federal government will contribute $60 million of the estimated $650 million cost, subject to negotiation of satisfactory terms and conditions between the federal government and the Provincial Urban Transportation Authority. The first stage connecting New Westminster

and Vancouver is scheduled to be completed by 1986. A 1.5 km section of the final line in the downtown area of Vancouver will be tested in mid-1983.

Further sales may occur in Washington where the Metro system is in final negotiations to authorize an evaluation of steerable axle trucks on its rolling stock.[29] Washington has encountered severe maintenance problems in conventional technology. Also, the previously described method of welding vehicle bodies may be sold abroad. UTDC bid on rapid transit projects worth $330 million in Miami and Los Angeles, and in March 1980, Sumitomo was granted Japanese marketing rights to advance the urban transit system developed by UTDC. In a 1980 statement, the president of UTDC noted the following possible sales in addition to Vancouver: Hamilton $110 million, Los Angeles $130 million, Detroit $165 million and Miami $195 million. Competitors for these sales were seen to be two U.S. firms, Westinghouse and Vought and a French firm, Otis-Matra.[30]

By 1981, the total cost of the ICTS to-date was reported to be over $70 million and it was estimated that the cost per mile of ICTS versus the subway was $25 million versus $75 million.[31] Consideration was being given to the idea of selling UTDC and its product technology to the private sector.[32] The issue which had arisen was whether UTDC could continue without entering the manufacturing stage, and, if it did become a manufacturer or even a principal contractor, whether it should be government owned.

TDC AND THE BOMBARDIER CONSORTIUM (1973-1978)

The federal government's strong interest in ICTS dates from 1973, when TDC awarded a contract to Hawker Siddeley to carry out advanced work in technological areas applicable to ICTS. From this date, complementary developments took place at the federal and provincial levels. At this time the Ontario government was introducing its new urban transportation policy, one part of which was the creation of OTDC to hold and exercise the Krauss-Maffei license rights for maglev technology. In December 1974 the federal government had issued to all provinces a proposal to jointly turn the OTDC into a national rather than a provincial entity. This offer was declined. Hawker Siddeley had been one of three firms with intermediate capacity transit systems chosen for evaluation in 1972 by the Ontario Department of Transportation and Communications - the other two were Ford and Krauss-Maffei. The last was selected by the Ontario government.

The Hawker Siddeley study for TDC was submitted in April 1974 and entitled, Advanced Technology Study Intermediate Capacity Transit. This study accepted a definition of ICT as a system capable of handling 2000-20,000 passengers per hour per direction (pphpd). It discussed a 40-passenger light linear induction motor (LIM) steel wheel on rail vehicle including power and control equipment. The two volumes of the study dealt with Vehicle Dynamics and Vehicle Stability, and with Power Supply and Propulsion Control. TDC's support resulted in part from a concern that the futuristic technology of the maglev project in Ontario might encounter problems.

The Hawker Siddeley study led TDC to make a request for proposals for a detailed concept definition of an ICTS. TDC established the following specifications for the project in 1974:

The ICTS should -

1. consider possible applications for use in primary trunk corridors, networks as in central business areas, and be capable of underground, at grade or elevated alignment,
2. have a capacity of 2,000-20,000 pphpd, and use an exclusive automated right of way,
3. have minimum intrusion re space, visual aesthetic impact, interference with other traffic, noise, vibration, the electro-magnetic spectrum and particulate pollution.
4. have high service levels and automated controls,
5. be based on steel wheel technology,
6. use existing rights of way where possible, but can consider new ones: should examine how to acquire right of way,
7. have no obligation to adhere to AAR or other railway standards, and
8. be operable either manually or automatically.

Other areas covered by the study were to be a determination of the size of the ICTS based on economic considerations, and consideration of fly wheel energy storage, linear induction motors, and resilient wheels.

These specifications were reduced to the following:

Design Objectives

1. Capacity range of 4,000-20,000 pphpd
2. Subway type service
3. Low capital and operating costs
4. Adaptable to operation on existing rights of way.

Design Guidelines

1. Electric propulsion
2. Steel wheel on steel rail
3. Small modular vehicles
4. Fully automated operation

The fact that steel wheel on rail operates well without the need for guideway heating under Canadian winter conditions was recognized as a major advantage of this type of system. Steel wheel on rail was also a well-proven technology and as such its use would increase the likelihood of the successful development of a prototype by 1980. The specification of at grade or elevated guideway recognized that there would be a cost saving of $20-$25 million per mile if underground construction was avoided.

The following groups submitted bids on the TDA proposal by May 30, 1974:

Prime Contractors	Subcontractors
Bombardier	CIMT, BBC, Matra and others
Canadair	Boeing Vertol
GM Canada	GM U.S., Transport Systems, D.C., C.P. Consulting Services, N.D. Lea & Associates
Hawker Siddeley	Others
OTDC	SPAR Aerospace, Transurban Systems Group (K-M) - Canada Systems Group, MLW Industries Ltd.

In December 1974, TDA selected the Bombardier consortium and awarded a contract of $1,470,000. The work was to be divided between the members of the consortium as follows:

Systems and Software

Program Management - Bombardier
Systems Design - Bombardier and Matra
Operations - Bombardier and Matra
Technical Coordination - Joint project group

Hardware Analysis

Vehicle - Bombardier and CIMT-Lorraine
Propulsion - BBC and Societé de Traction
CEM-OERLIKOW
Command and Control - CAE Electronics and Matra

Consultants included:

Marwick and Associates
Canalog and STCO.

The subcontractors who worked with Bombardier were related in various ways. CEM-OERLIKOW was owned by Brown Boveri, and Matra had an interest in the company. Brown Boveri Canada Ltd. was a direct subsidiary of Brown Boveri Switzerland. CIMT Lorraine was a majority-owned subsidiary of Matra, but had no subsidiary operation in Canada. These subcontractors were basically French and Swiss firms. CIMT-Lorraine had had a previous association with Bombardier as a result of a ten-year agreement signed in 1963 to serve as a vehicle design consultant for Canadian Vickers in building the Montreal Metro cars. The agreement ended in 1973 and Canadian Vickers chose not to renew it. CIMT was then retained by Bombardier. Bombardier and Matra were the two senior partners in the consortium. Matra sent two engineers to Canada on a full time basis and a number on a shorter term basis. Bombardier supplied the project manager.

Although the Bombardier consortium was selected in December 1974, the contract with TDA was not signed until December 1975. In the intervening period, the Ontario government and UTDC raised questions about the desirability of fragmenting ICTS development work in Canada. In addition, some federal departments were reluctant to support TDA's initiative without assurances that the proposed study would, if successful, result in the funding of a demonstration project. Bombardier and UTDC met to discuss possible means of cooperation, but no direct cooperation was forthcoming. In the end, UTDC had an observer on the Bombardier consortium's steering committee which consisted of senior officers from TDC, and representatives from other federal government organizations. This observer had access to all the progress reports. Meanwhile Bombardier did not have similar access to comparable work which was being undertaken by UTDC.

Technical Design

The Bombardier consortium proposed the following systems:

Propulsion System

Two chopper controlled 125 kw DC (not LIM) motors per car were proposed with power pickup at 600 volts DC via a third rail. By 1978, all the problems associated with snow removal for a third rail had yet to be resolved, particularly since some type of sidewall barrier would be necessary to protect the right of way against intrusion. Each vehicle would be bi-directional and operate alone, or in a train consisting of up to three cars. At a minimum headway of 72 seconds, the maximum line capacity at 114 passengers per vehicle would be

17,000 pphpd. Under crush loading conditions a maximum capacity of 20,700 pphpd could be achieved.[33] The choice of an electric motor stemmed from the fact that only electric energy was felt to provide suitable, clean, pollution-free characteristics for propelling a modern mass transit system. Innovative features such as fly wheel energy storage were to be further investigated to provide improved energy efficiency and possibly eliminate the need for continuous line electrification.

Command and Control

The short headways, planned high frequency of service, and desire to reduce operating cost dictated fully automated driverless vehicles. The system proposed was a variant of one originally conceived by Matra for use on a system installed in Lille, France. It features distributed logic throughout the system in order to aid reliability. Vehicle position, overspeed protection and communication were obtained from cables laid along the length of the track. Labour costs in 1975 accounted for 60-70 percent of the operating expenses of a public transit system. This percentage has been steadily rising, further increasing transit deficits, and it was felt that automation would help reduce these deficits.

Guideway

It was proposed that the guideway should be at grade level for reasons of cost, and because an elevated guideway would be aesthetically unacceptable in a modern urban environment. At grade level, the guideways could be inserted on existing railway or urban street rights of way. Other studies by TDC favoured railway insertion, but saw difficulties with urban street insertion.

The Market

TDC's support for ICTS noted studies that had been made in Canada of the travel demand in cities. For example, a study of 23 urban centres in Canada with populations in excess of 100,000, estimated that there would be 42 travel corridors in eight cities with travel capacity in excess of 40,000 pphpd. The details in Exhibit 14 show the distribution of corridors by forecast demand: it is estimated that there are 24 corridors with a demand for 4,000 to 6,000 pphpd - the length of the 24 corridors is 457 km or an average of about 19 km per corridor. The potential market would be larger if foreign urban centres were included.

Final reports were scheduled to be submitted by the Bombardier consortium in 1977, but were not ready until 1978. To ensure delivery, TDA held back $150,000 (10%). The delay resulted from the fact that initial reports had to receive extensive revision. It should be noted that the management of any project involving a consortium of companies, especially where different nationalities and language are concerned, is liable to encounter difficulties of coordination. Each consortium member tends to give the project a different priority.

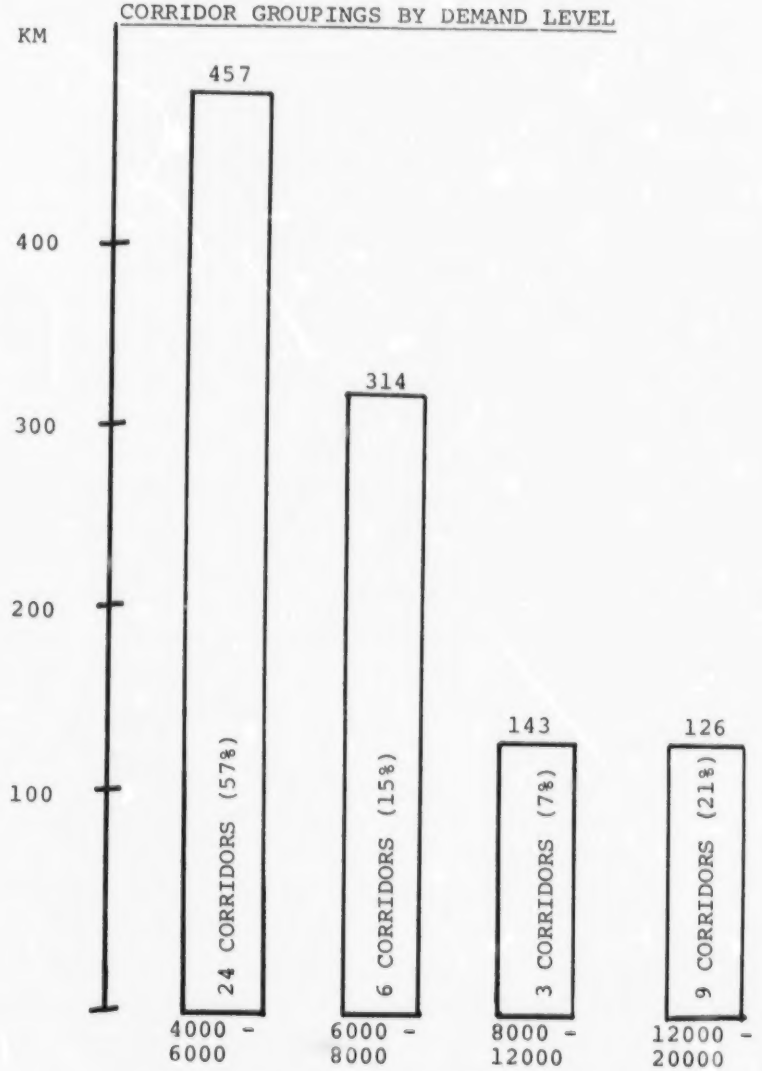
TDC concluded that the design teams tended to take a cautious approach, choosing known technology when it could be adapted to ICTS use.

> The result has been a system design having a relatively low technical risk which could be implemented without the need for a major research program, although some development period would be necessary.[34]

The members of the consortium attributed the delay

EXHIBIT 14

CORRIDOR GROUPINGS BY DEMAND LEVEL



SOURCE: Rudback, op.cit., p. 8.

in completing the project to two factors. First, there was felt to be little incentive to complete the task. The rival UTDC development project appeared to have extensive funding and commitment to implementation. The Bombardier consortium felt that it was involved in a paper exercise and that there was no prospect for implementation. Second, the level of funding was considered inadequate for the extent of the communications that were needed between the engineers and technicians of the member firms.

Some of the characteristics of the Bombardier consortium's proposed vehicle and system are listed in Exhibit 15, and contrasted with the UTDC vehicle and system which were being designed simultaneously. There were a number of similarities.

TDC entered into a further contract with Bombardier whereby Bombardier is to evaluate a special bogie design which has the potential for reducing capital and operating costs of an ICTS. A weight and cost comparison is to be made between this bogie and others of more conventional design. This project is scheduled for delivery in 1983 at a cost to TDC of about $40,000.

In 1978, TDC and Bombardier discussed another project. This was for follow-on hardware development which was to involve the design and construction of two small, lightweight fabricated bogies. The two prototype bogies were to be mounted under a Montreal Metro-type body shell, which would be suitably modified to fulfil the test requirements. Once assembled, the test vehicle was submitted to a test program on a 1.6 km electrified line near the Bombardier plant at Lapocatière. The

EXHIBIT 15

ICTS - SELECTED SYSTEM CHARACTERISTICS

	Bombardier	UTDC
Basic Capacity	17,000 PPHPD	15,000 PPHPD
Maximum Capacity	20,000 PPHPD	20,000 PPHPD
Minimum Consist	1 car	2 cars
Consist at Capacity	3 cars	4 cars
Train Length at Capadity	46 M	48 M
Stations	On Line	On or Off Line
Station Spacing (Avg.)	1.25 KM	1.25 KM
Automatic Control	Variable Moving Block	
Minimum Headway	72 sec.	60 sec.

ICTS - SELECTED VEHICLE CHARACTERISTICS

	Bombardier	UTDC
Length (Overall)	15.72 M	12.7 M
Width	3.00 M	2.50 M
Height	3.34 M	3.05 M
Floor Height	0.90 M	0.76 M
Normal Capacity	114	74
- Seated	48	35
- Standing	66	39
Crush Load	138	85
Propulsion	Rotary DC	LIM
Maximum Speed	20M/S(45 MPH)	20M/S (45 MPH)
Weight Empty	21,060 KG	13,400 KG
Weight Loaded (Crush)	30,680 KG	19,350 KG
Seating Ratio (Normal)	42%	47%
Floor Area/Pass.(Normal)	0.34 M^2	0.36 M^2
Weight/Pass. (Crush)	222 KG	228 KG

SOURCE: Rudback, op.cit., 1978, p. 5.

Quebec government, having a potential future interest in ICTS and wishing to build up this technological expertise within Bombardier, is playing a lead role in these recent projects. The $1,767,000 cost of this project was shared as follows:

TDC	-	$540,000
Quebec	-	$1,027,000
Bombardier	-	$200,000

The contract duration was March 1979 - March 1981. By 1982, the federal government was supporting both the installation of the ICTS in Vancouver and the Bombardier development of a light weight bogie.

Subsequent to the completion of this study, UTDC contracted with Venturetrans Manufacturing Ltd., a subsidiary of Toronto Iron Works, to manufacture the vehicles for the ICTS. Venturetrans will operate at UTDC's Kingston site. Metrocan, a subsidiary of UTDC, will undertake the engineering design and marketing of the vehicles. Thus, Venturetrans will use Metrocan's designs in its manufacturing operation, and will return the completed product to Metrocan. At the outset, it appears that Venturetrans will be primarily an assembly operation with value-added accounting for about 30 percent of its output.

FOOTNOTES TO CHAPTER 5

1. Statement (Press Release) by Prime Minister William Davis in the Legislature of Ontario, June 3rd, 1971, p. 4.

2. Ibid., p. 4.

3. Ibid., p. 3.

4. Department of Transportation and Communications, Ontario, A Study for the Selection of an Intermediate Capacity Public System, January 1972, p. 1.

5. Ibid., pp. 1 and 2.

6. Ibid., pp. 2-6.

7. Remarks by Hon W.G. Davis to the Roads and Transportation Association of Canada, Toronto, May 11, 1973.

8. The Toronto Transit Commission commented on the development of an ICTS by noting that it could provide feeder services to the main subway system and could be used in relatively low density areas - see Toronto Transit Commission, A Concept for Integrated Rapid Transit and Commuter Rail Systems in the Metropolitan Region, Feb. 1973.

9. Ontario Ministry of Transportation and Communications Research and Development Division, Intermediate Capacity Transit - Ontario's Program, Feb. 1974, p. 5.

10. Ibid., p. 5.

11. There is a joint statement by Premiers Davis and Lougheed of Ontario and Alberta announcing the intention of Alberta to invest in UTDC.

12. Remarks by Hon. W.G. David, Canadian Transit Industrial Conference, Ontario Science Centre, Oct. 23, 1973, p. 5.

13. K.W. Foley, Press Release, News Media Conference, Toronto, May 1, 1974. In a presentation on Oct. 16, 1980 to the Canadian Senate Subcommittee of Foreign Affairs, Mr. Foley stated that UTDC is not in the business of manufacturing vehicles, p. 5.

14. See K.W. Foley, Address to Canadian Urban Transit Association, Calgary, June 25, 1974, p. 21.

15. K.W. Foley, GO-URBAN and the Transit Demonstration System: Development Process and Progress to Date, Ontario Transportation Development Corporation, April 9, 1974, pp. 12-13.

16. See statement by Hon. J. Rhodes, Minister of Transportation and Communications, in the Ontario Legislature, Nov. 13, 1974.

17. K.W. Foley, Press Release, Toronto, September 16, 1974.

18. OTDC, Detailed Report for a Study for Concept Definition of an Intermediate Capacity Transit System, Toronto, Oct. 4, 1974. At this point, UTDC referred to the GO-URBAN project as having had a 'fantasy-like quality'. However 'maglev' technology was still being considered along with alternative suspension systems for the ICTS - see K.W. Foley, Press Release, Ontario Urban Transit Assoc., Toronto, Feb. 28, 1975, pp. 16 and 20. It was only later that 'maglev' was dropped in favour of steel wheel on rail suspension. At this time it was still anticipated that the Federal and other provincial governments would invest in UTDC. See also statement by Hon. J.R. Rhodes, Minister for Transportation and Communications, Ontario's Legislature, April 14, 1975, p. 9.

19. UTDC, ICTS Development Program, Report on Phases 1 and 2 and Recommendation for Phase 3 (Vol. 1), p. 1.

20. Ibid., p. 23 and K.W. Foley, Press Release, Canadian Foundry Association Annual Meeting, May 11, 1976, p. 11.

21. See K.W. Foley, Press Release, Joint Meeting on Transportation Policy Issues of the Canadian Transportation Research Forum and the Transportation Research Forum, Toronto, Nov. 4, 1975, pp. 6 and 15.

22. Adapted from C. Maurer, Popular Science, Dec. 1980, p. 76.

23. UTDC, ICTS Brochure.

24. UTDC Statement.

25. DOFASCO Brochure on Custom Designed Railroad Trucks.

26. The trucks for the Vancouver contract will be produced in Canada. As of 1982 it is intended to purchase the components and assemble them at the UTDC facility in Kingston.

27. Details of the operational requirements of the ICTS had also been studied and were presented in a report - see UTDC, Intermediate Capacity System, Operational Requirement, Toronto, July 15, 1976.

28. See Barton Myers Associates, UTDC Urban Design Study, Toronto, October 1978.

29. A detailed description of the ICTS can be found in UTDC's submission to UMTA of the U.S. Dept. of Transport, ICTS System Definition, July 1980.

30. Senate of Canada, Standing Committee on Foreign Affairs, Oct. 16, 1980, p. 11:21. The Government of Ontario announced that Detroit had purchased an ICTS for $110 million, Ottawa Citizen, April 24, 1982, p. 1.

31. K.W. Foley, Press Release, Financial Post Conference on Industrial Strategy, Feb. 26, 1981, pp. 6, 8 and 10.

32. Ibid., pp. 15-16.

33. N.E. Rudback, Canadian ICTS Development, Paper presented to Conference on Automated Guideway Transit Technology Development, Feb. 28-March 2, 1978, Cambridge, Mass., p. 5.

34. Rudback, op.cit., 1978, p. 5.

CHAPTER 6

SUMMARY OBSERVATIONS

THE LRC TRAIN

Success or Failure

The final evaluation of an innovation comes a number of years after the process begins unless failure becomes obvious. In the case of the LRC the economic benefits will increase with the number of train sets sold either outright or under license, and in terms of external benefits related to spin-off projects which can be traced to the original process of innovation. Against these benefits will have to be measured the costs involved. While time is needed for a final assessment, the passage of time creates a problem, especially in terms of measuring external benefits, because other factors are introduced which influence the outcome of the project, and it is difficult to determine what and how much of the outcome was due to the original innovation.

In 1982, the two extreme cases which could be made regarding the LRC project might be as follows: first a favourable, and second an unfavourable interpretation of the facts.

Scenario a.

The process of innovation which began in 1967, in the wake of an unfortunate experience with the Turbotrain, has resulted in 1982 with the production of 12 and the sale of 10 train sets, with the possibility of substantial further sales. The project has been conducted in Canada by a consortium of Canadian-owned companies which have combined their transportation-related

expertise to develop the project. The process of innovation has been particularly challenging because the consortium has had to accept the fact that the trains would operate on a right-of-way which is shared with freight traffic, has numerous grade crossings, lacks a modernised signalling system, and which has a roadbed in need of up-grading. Success has been achieved by the federal government being an active participant in, and promoter of, the project. Considerable spin-off work has already resulted in contracts for the member firms of the consortium.

Scenario b.

The project has taken thirteen years to develop a train which is capable of operating at 125 mph, but will only be able to operate at 95 mph because of conditions affecting other parts of the rail system. The travel time between Montreal and Toronto, for example, will be marginally different from the service currently provided. The project could have been undertaken in less time and for less money if the railways had had a clear policy for passenger rail service, and if the government had made known what this policy was to be. The actual innovation required was relatively minor, namely the development of a tilting mechanism for the trucks, and the design of light weight coaches with low centres of gravity. Tilting mechanisms were already in existence and had been used in trains. In fact, because the train would only travel at 95 mph, it is questionable whether tilting is required at all.

The principal market for the trains so far is VIA rail, which is owned by the government, and which provides highly subsidized passenger rail service. AMTRAK,

which had a lease-purchase agreement on two train sets, has not exercised the purchase option and has returned the two trains to Canada. The government has promoted the project with grants from PAIT and TDA, has been responsible for setting the policies and providing the subsidies for passenger rail service, and owns the railroad which supplies most of the passenger service in Canada. The government has ended up buying the product which it brought into existence with its own subsidies while the demand for rail passenger was declining.

Qualifications can be made to both these extreme cases, and in time the facts may result in an evaluation somewhere in-between. At the present, however, the LRC case does allow for some comments to be made about the process of innovation in transportation equipment. These will be dealt with under the following headings - the role of government, consortium arrangements and railways as a system.

The Role of Government

Rail passenger travel has been on the decline as a passenger mode at least since 1945. Various reasons have been put forward for this decline. One explanation is that passenger rail service deteriorated as a result of lack of investment in railway infrastructure and railway equipment, causing passengers to turn to alternative modes. An alternative explanation is that improvements took place in other modes such as car, bus and air travel which drew passengers away from rail travel, and which made it unattractive for railways to modernise their equipment and facilities. These alternative modes provided passengers with shorter travel time from points of origin to ultimate destination. This is especially

the case for the automobile, whereas buses and planes operate between terminals and the passenger still has to travel to and from the terminal at each end. However, as long as the combination of time and cost of other modes is attractive to the passenger relative to rail, the passenger will tend to gravitate towards these modes.

The question then arises as to why the railways did not respond to the competition for passenger rail service. One answer is that they did, but the response was to de-emphasise their rail operations and to expand and diversify into other areas. For example, Canadian Pacific diversified into natural resources, real estate, shipping, trucking and airlines, the last being one of the competitors to passenger rail service. CNR has emphasised expansion in rail freight services, which is where most railways in North America concentrate their efforts, has ship and trucking interests, and has recently acquired oil and gas interests.

A further reason why the railways did not fight back when passenger rail service became unprofitable was because government is alleged to have provided greater subsidies to road and air travel than it did to rail travel. For example, cars and buses were provided with the highway and street infrastructure, and planes with the airport and air traffic control infrastructure at very low cost relative to the cost to the railways for maintaining their roadbeds. Thus, government either decided to de-emphasise passenger rail service, or were successfully lobbied by the alternative modes to subsidise their infrastructure, and unsuccessfully lobbied by the railways.

These circumstances are pertinent to the LRC project because of the need to explain why government would spend nearly $2 million on a passenger rail project over a period of thirteen years if it was not committed to promoting passenger rail service. On the surface, it does not appear a rational expenditure of government funds. Assuming that both politicians and bureaucrats have nothing to gain by making decisions for which they will be later criticised, and assuming that there are alternative projects on which the $2 million can be spent, the question remains as to why choose the LRC project.

One answer seems to be that it is wrong to view government as being monolithic as far as transportation policy, especially where rail transportation, is concerned. At the federal level, there are several departments, agencies and corporations interested in railways. CNR, a Crown corporation, operates a railway. The Canadian Transport Commission (CTC) is a regulatory agency. Transport Canada is a government department where rail policy is developed, and through it the Transportation Development Centre has responsibility for promoting research in transportation. In addition, the Department of Industry, Trade and Commerce promotes research and development and the industrial development of Canada's transportation equipment manufacturers. There is no administrative or political process whereby all these strands of policy are brought to a head except at the cabinet level, and it seems doubtful that cabinet would spend much time reconciling the interests of CNR, the CTC, Transport Canada and Industry, Trade and Commerce. It is true that a number of these policy components report to the Ministry of Transport, but the department has such extensive interests and responsibilities

including those of competing modes, that it cannot itself be viewed as an organization without conflicting interests.

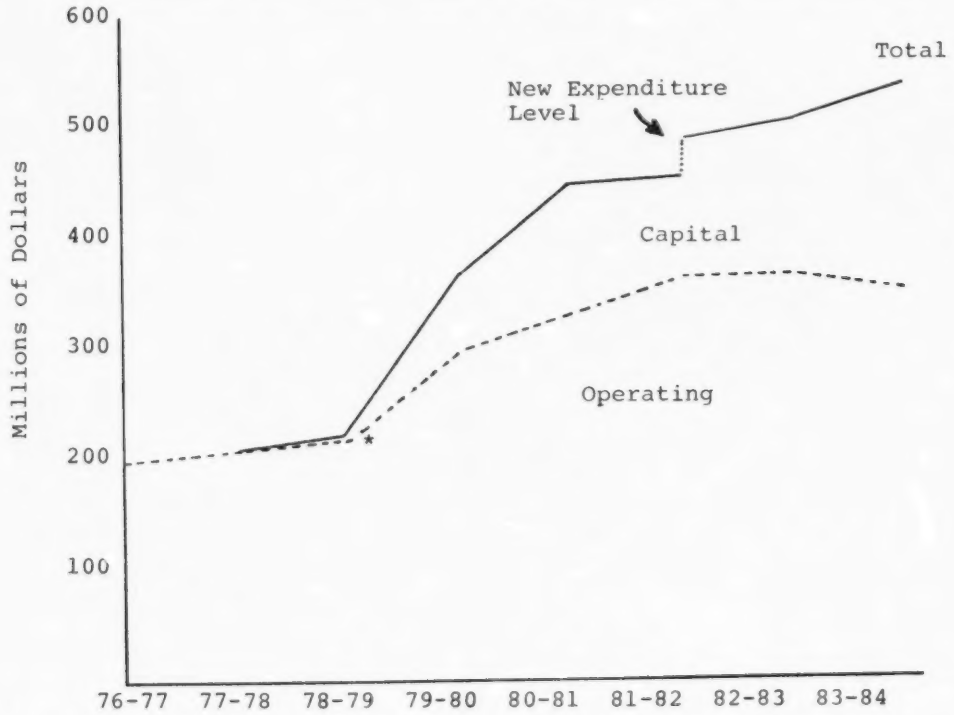
It appears that those parts of government which promote research and development and industrial development provided the main impetus to the LRC project, namely TDA and DITC. The principal rationale would therefore have been the immediate and spin-off industrial benefits to Canada if the project was successful, with success being measured over a period stretching beyond 1981.

A major observation regarding the LRC project is that there was no detailed marketing study made for the project by any of the parties involved, at a time when there were clear indications that the demand for passenger rail service was on the decline in North America. The requirement for a market study would not be necessary if it was clear to the policy planners how the LRC equipment would affect government funding. The actual and projected funding for rail passenger service is shown in Exhibit 16.

From 1967 to 1978, the government had funded the operating losses of the railways up to 80 percent of the loss and the funding had risen to about $200 million. In 1978, the losses were funded 100 percent through VIA Rail with provision made for capital and operating expenditures. Payment for the LRC equipment represents part of the capital funding, and it is argued that without new equipment the operating costs would have risen substantially, and that in future years the total funding of passenger rail service would be higher than the total

EXHIBIT 16

ACTUAL AND PROJECTED GOVERNMENT FUNDING OF VIA RAIL INC.



*VIA assumes service at 100% government support of loss.
SOURCE: Transport Canada

capital plus operating funding shown in Exhibit 16 (about $525 million in 1983-84). One rationale for the LRC project is that it provides a way of reducing the rate of increase of the funding which the government supplies to support the provision of passenger rail service in Canada. In brief, one argument is that the LRC project was undertaken not just to reduce the loss, but to reduce the expected rate of increase of the loss if passenger service is to be continued.

Consortium Arrangements

The management of innovation is recognised to be a difficult task, but one which is compounded when it is a consortium of private firms which has to be managed, and these firms have to interact with government departments, agencies and a Crown corporation. The consortium of three companies plus their subcontractors appeared to work well together, but each firm had its own view of and interest in the project. Alcan's interest in transportation is as an outlet for aluminum, Dofasco's is as an outlet for steel, and MLW-Bombardier's as a manufacturer of locomotives and rolling stock. In each case, the firms' interests were conditioned by the market for rail passenger travel and the fact that there were limited market opportunities for manufacturing passenger equipment. For example, the market for freight trucks in North America is much more attractive to Dofasco than the market for passenger trucks.

At different points throughout the LRC project, a different company took the lead in promoting the project. Once the prototype locomotive and coach had been built and tested, the lead was taken by MLW-Bombardier which would manufacture the train sets and market the product.

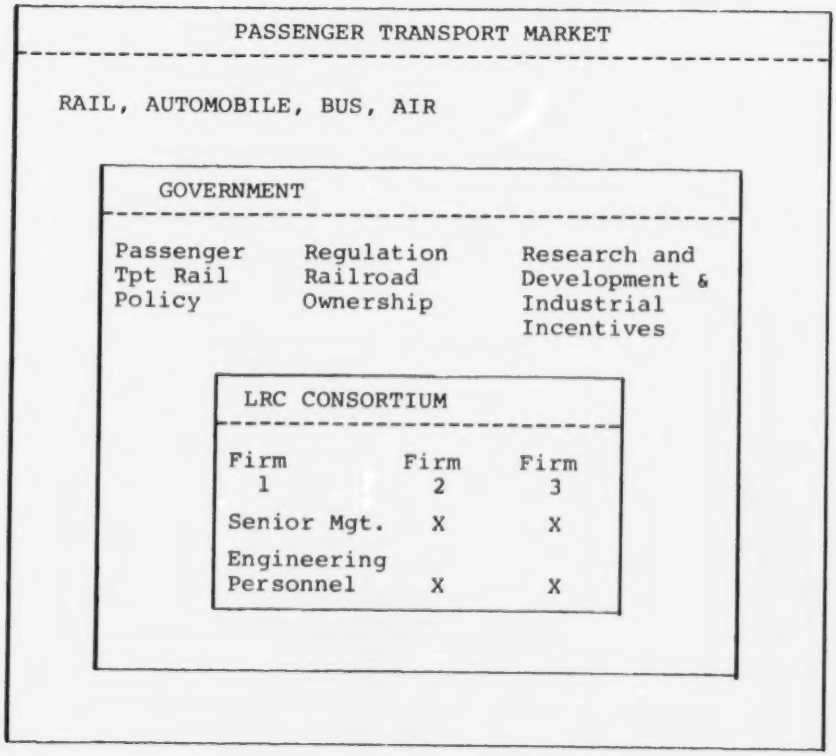
Support for the project within each company occurred at two levels, the engineering design personnel and the senior management to which these personnel reported. In a consortium arrangement there is a need not only to coordinate the three firms, but also the levels of decision-makers within each firm. When a project is extended over a long period of time, there are inevitably differences of opinion both within firms and between firms about the viability of the project and each firm's commitment to it. Also, personnel change positions within their organizations.

The views and actions of the decision-makers within the consortium were influenced by government in several ways. The most important positive influence was the catalytic role played by DITC and TDA in providing financial support. At the same time, CNR was restraining the consortium's enthusiasm by requiring ever-more demanding tests to be undertaken, and by stating their views concerning limited possibilities for passenger rail service. CNR was itself conditioned by the passage of the National Transportation Act in 1967 and the formation of VIA rail in 1977, which formalised the method by which passenger rail losses would be shared by the government and the railroad companies.

Diagrammatically, one can visualise the context of the innovation as shown in Exhibit 17. Within each member firm of the consortium there are different functional executives in charge of finance and engineering who must interact within each firm, and between member firms. In turn, the consortium operates within a framework of government rail transportation policies which are themselves a part of the policy environment for the

EXHIBIT 17

THE SETTING FOR THE LRC PROJECT



passenger transportation market, including road and air as well as rail. Numerous personal and organizational pressures resulted and influenced the evolution of the project as a result of the existence of these factors.

In this type of setting, interpersonal relations are important and there are clear differences between the viewpoints of bureaucrat and business executives. In a research and development project, the engineer-businessman wants to be able to get on with the job unhindered by report writing and constantly being made accountable for his actions. On the other hand, the bureaucrat in funding a project is responsible for the prudent management of public funds, and will be criticised for failing to make firms accountable for the funds provided. Thus, the bureaucrat tends to require regular detailed reports. These two conflicting outlooks produce friction in managing a project.

The problem lies in the fact that government is put into the position of being a venture capitalist. Typically private sector venture capitalists find that about one in ten projects can be expected to be successful. The politician and the bureaucrat have difficulty in justifying publicly nine failures for every one success, especially when the success may accrue not to the politician, who was there when the decision was made to fund the research and development, but to the one who is in office some years later, when the project bears fruit.

Railways as a System

Successful innovators of passenger rail service need to recognise that the service provided is the result of viewing railways as a system for the movement of people. The system includes access (embarkation and disembarkation) as well as carriage. In turn, the system is made up of travel to the station, the station itself, the railbed, the signalling system as well as the locomotive and coaches. As has been shown, the equipment itself is the joint product of manufacturers from various industries, e.g., aluminum, steel, electronic, and locomotive and coach manufacturers. Firms from other industries produce other parts of the railway infrastructure.

In order to deliver rapid and comfortable passenger rail service, the LRC project was addressed to one part of the system only, namely the locomotive and coach. As a result of not improving the railbed, grade crossings or signalling system the comfort objective could be achieved, but not the speed, because the rest of the rail infrastructure would not allow for it. For example, there are still over 200 grade crossings between Montreal and Toronto, and the LRC train which can operate at 125 mph will only be able to run at 95 mph.

The innovation which resulted in the LRC project may be viewed as a success in terms of its potential, but a failure in terms of its use, if passengers are not attracted to rail travel because it does not compete with other passenger modes in terms of speed and reliability.

The three members of the LRC consortium had expertise

in transportation-related projects. Aluminum is used extensively in aircraft, and Dofasco and MLW-Bombardier have experience in railroad equipment. The Turbotrain, on the other hand, was the product of design-engineering work done in the U.S. by the United Aircraft Corporation. There has been a tendency for aircraft manufacturers to encounter severe problems when they attempt to diversify into building railway and ground transportation equipment. UAC is one example, but there are other cases in North America.

From the viewpoint of the process of innovation, the interesting question is why engineering skills do not appear to be easily transferable between aircraft and ground transportation equipment manufacturing.[1] Possible answers include the following:[2]

1. Aircraft are built to very rigid specifications which are laid out in manuals and which are checked and verified by government inspectors. Aircraft manufacturers are very sensitive to weight control, and personnel will be responsible for checking on and recording the weight of each identifiable part.

   Railroad equipment is manufactured using engineering experience and rules of thumb (an art) and there is much less concern with weight.

2. Aircraft are subject to rigid maintenance schedules, such that the equipment is continually being rebuilt as a result of repairs and replacement of parts.

   Railroads maintain their equipment, but in many cases such as freight rolling stock, the owner may not see his freight car for years while it is

located in another part of North America. Railway equipment must thus be able to operate for long periods without careful maintenance.

3. The design requirements in terms of the stress factors for aircraft taking off, landing and while in flight are different to the requirements for railway rolling stock which is constantly in touch with the ground via rails, and where the roadbed is often in poor condition.

These three factors coalesced in the Turbotrain project where aircraft engineers designed a train which was in a way too sensitive to operate well, and which had to be maintained by railway personnel who were not familiar with the design or the type of equipment, especially gas turbine engines. This is not to suggest that engineers cannot transfer skills from one area to another, or that management cannot hire the right type of skills and manage a new project. Gas turbine engines are used satisfactorily by railways in Europe. The fact is, however, that the UAC-Turbotrain example is not an isolated case, and the process of innovation in railroad transportation has illustrated these engineering-specific problems when aircraft manufacturers have attempted to diversify into railway equipment.

THE ICTS SYSTEM

Success or Failure

The process of innovation leading to the ICTS began around 1973 with the creation of the OTDC (the forerunner of UTDC) and with the award of a contract by TDC to Hawker Siddeley to undertake advanced work in technological

areas applicable to ICTS. The development process has been going on for more than eight years. Over $70 million has been spent on the project by the province of Ontario, and about $1.5 million has been spent by the federal government. A final evaluation of the technical and commercial success of the ICTS will have to occur some time in the future after it has been in operational use in Vancouver and in other cities which adopt the system.

UTDC managed the ICTS project in order to ensure that industrial benefits would accrue to Canada. Wherever possible, technology was transferred to Canada either by way of licensing, e.g., LIM technology, or by the establishment of a foreign subsidiary with a product mandate, e.g., SEL Canada. At the same time, provision has been made for the creation of an industrial park surrounding the UTDC test track and facilities at Kingston. This park may attract firms involved in transport-related work.

The ICTS embodied organizational as well as technical and commercial innovation, especially with regard to the institutional arrangements put into place by the government of Ontario in the establishment of UTDC. The case illustrates aspects of what Scherer referred to in connection with the aerospace industry as the "special institutions...created to shift from producers to the government what might otherwise be intolerable financial risks", the "grey area between private and public enterprise", and a "non market buyer-seller relationship".[3] In these circumstances profit levels cannot be used as a measure of performance because they result in part on actions taken by the government

regarding procurement and subsidies for research and development.[4]

The Ontario government was imaginative in its willingness to engage in organizational innovation in attempting to resolve its urban transportation problems, and at the same time generate industrial spinoffs in Ontario. The organizational flexibility also allowed the process of innovation to recover and continue after it had been subjected to a staggering blow with the decision that 'maglev' technology was unsuitable for urban transportation.

Role of Government

The ICTS has involved at least two levels of government in Canada, the federal government and the Ontario and Quebec provincial governments. In addition, the municipal governments in Hamilton and Vancouver have been involved as buyers of the system. The financing of the sales by UTDC requires interaction between all three levels of government.

In the federal and Ontario governments, the ICTS had its product champion in TDC and UTDC respectively. This leadership on the government side provided impetus to the project. In Ontario, leadership was provided both at the political and at the bureaucratic levels, because of the commitment to urban transportation which this government has had for over a decade, and dating back to its involvement with maglev technology. Undoubtedly, the continuity of one party and one premier in office in Ontario over the past decade has helped to ensure the continuity of the ICTS project. The premier has supported the project and the president of UTDC

has had a close working relationship with the premier.

Another factor to note is that UTDC has engaged in public relations with the legislature and the public. The president has made numerous statements, and the corporation has issued materials which explain in detail its philosophy, projects, and results. Publicity of this nature presents problems for a government organization, because it provides information both for the critics and for the supporters of the government's urban transportation program. In the area of research and development, where in the initial years of a project the high visibility items are the project's costs, and the benefits, if realised, are some way off in the future, then engaging in publicity is a risky operation. It serves to focus the taxpayers' attention on the fact that the government is playing the role of a venture capitalist using the taxpayers' funds.

The federal government, through TDC, chose to support in 1974 a Quebec-based consortium to work on an ICTS. This decision came at a time when the province of Ontario withdrew its support for Krauss-Maffei maglev technology. It was felt in Ontario that the contract should have been undertaken by the UTDC consortium which already had the expertise. Discussions on this issue delayed for one year the start of work on the TDC contract, after it was signed in 1974. The TDC-supported consortium, led by Bombardier, provided the concept definition of an ICTS, which was similar to that which had already been developed by Matra, a European company, which was a member of the consortium.

The work done on the ICTS by the federal and Ontario

governments was in some ways parallel and in others complementary to each other. Different firms were involved in the two projects, which gives rise to the issue of whether two centres of excellence should be promoted concerning the development of a similar urban transportation system. One argument for two centres is that competition between the two will result in the development of a better system. Against this is the view that Canada has a small manufacturing base, and that emphasis should be placed on supporting one rather than two groups of firms, as a way of preventing the fragmentation of effort.

A related issue is the impact of federalism on purchasing policies. It was noted that the cities of Edmonton and Calgary purchased a foreign-built light rail system rather than contracting with Canadian firms in Ontario and Quebec to provide the equipment. There may be good economic reasons why the foreign equipment was preferred, but the fragmentation caused by provincial purchasing practices, together with federal and provincial government support of two ICTS projects involving different firms, indicates the problems that arise in a federal state, such as Canada, when it attempts to develop an industrial strategy.

Consortium Arrangements

An urban transportation project requires a consortium of companies for two reasons. First, transportation needs a systems approach in order to integrate vehicle equipment, command and control system and infrastructure (railbed, right of way, stations and maintenance facilities). Second, the vehicle is itself a collection of components manufactured by different companies, e.g.,

propulsion, trucks, and bodies. The required technology will have to be drawn from numerous sources, domestic and foreign, and coordinated and integrated in one place.

There are substantial costs involved in undertaking this type of innovation for the first time. However, as in aircraft manufacture, the existence of a learning curve[5] means that, in subsequent projects of the same or a related nature, these initial costs will be reduced, providing the expertise is kept and not dissipated.

The creation of the UTDC was aimed at promoting technological innovation and preventing its dissipation. The UTDC mandate is a) to develop innovative transit alternatives, b) to create a Canadian centre of excellence, c) to stimulate development of industry, d) to maximize return from research and development, and e) to avoid direct competition with the private sector. In pursuing and meeting these objectives, UTDC appears to be diversifying into production through its wholly owned subsidiary, Metro Canada Ltd., which, in June 1980, purchased the assets of the ground transportation business of Canadair Services Ltd., itself a wholly owned subsidiary of the federally owned Canadair Ltd. UTDC began with a clear statement that it would work with firms in the private sector. Events have led senior management to speculate whether it should engage in manufacturing, and whether it should sell the corporation to the private sector. UTDC acted as the catalyst for the consortium, but with successive stages of the innovation process it was found necessary to involve different firms and to engage in different contractual arrangements. As the stage of commercial production approaches, the decision

has to be made as to whether UTDC manages the project by contracting out the work, performs the work itself, or combines some combination of the two.

The UTDC consortium has involved a number of companies, some of which have left and others which have joined the group, e.g., Canadair, SPAR, Kilmer Von Nostrand, Rohr, SEL Canada, GEC, Dofasco, Alcan, and ABAM Engineers. The number of firms in the consortium presents problems of coordination. Moreover, the importance of the work to each firm,and thus their interest in it,will tend to differ. Individual managers and engineers play a key role in the process, and if the innovation is stretched over a long period of time, personnel tend to be reassigned within (or between) companies creating problems of continuity and commitment.

The TDC-backed consortium of firms worked on a project basis and on a smaller scale. The firms involved were both Canadian-owned and foreign-owned, and some problems were experienced in the liaison between the firms. The foreign firms, which had had previous urban transport design experience, influenced the design introduced into the Canadian project. An observer noted that the consortium ended up proposing an existing European-designed system for Canada. One problem with a consortium arrangement involving foreign firms is that the information generated during the project may flow out of Canada. Moreover, if there is no continuous project, such as a piece of equipment, for which the information is used, then the results of the innovation may be dissipated.

A Systems Approach

The ICTS, as its name implies, has been approached from the outset as a system, rather than as an individual piece of equipment, as in the case of the LRC train. Consequently, the consortium of firms associated with the ICTS were assembled so as to develop a light rail system, while the LRC consortium had a mandate to develop a piece of equipment, namely a train.

If the success of a transportation project is to be measured in terms of the level of service that it ultimately provides, then a systems approach would appear to be a necessary, but not a sufficient, condition for success. Without such an approach the project is almost certainly doomed to failure because only one part of the system is being attended to, and the remaining parts are likely to deny it the ability to improve the quality of service in a way which will attract passengers.

A systems approach to urban transportation requires an agent to coordinate the developmental work. It is not impossible to conceive that the coordinator would come from the private sector. However, it is not surprising, given the technical, commercial and political risks involved, and given government's role as a financier and as a provider of urban transportation services, that government would create an agency to be the coordinator.

INNOVATION AND PUBLIC-PRIVATE SECTOR RELATIONSHIPS

Government policy in support of research and development in urban transportation equipment is premised on the view that, left to its own devices, the private sector would under-invest in this type of activity. The question then arises as to how successful government policy is in promoting innovation in this area. In order to shed some light on this topic, the two case studies attempted an historical reconstruction of the development of the LRC train and the ICTS. Since the LRC train only began revenue operation in 1981, it is not possible to assess ultimate commercial success, which can only occur some years hence as a result of domestic and export sales, and spinoff activity. The ICTS is yet to be used in commercial operation.

In this section of the summary, the findings in the two cases will be related to the literature on the process of innovation, especially as it deals with those factors which have been associated with successful innovation, and it will include factors which have been noted to impede the process. In addition, mention will be made of issues which appear to be peculiar to this industry, and to its institutional (public and private sector) arrangements.

The Process of Innovation

Transport Canada has identified a four-stage innovation cycle - see Exhibit 18. These four stages are concerned with applied research and development activities as opposed to basic research.[6] The development of both the LRC train and the ICTS can be associated with each stage. It will be noted that the ICTS has a

EXHIBIT 18

INNOVATIONAL CYCLE

Stages	Description
I. Concept Generation	Applied research and feasibility studies.
II. Concept Validation	Experimentation and early prototype development.
III. Product Development	Construction and testing of full scale pre-production prototype.
IV. Operational Demonstration	Demonstration and evaluation of the first production prototype models in operational service prior to (and essential for) widespread acceptance and use of the new technology.

definite Stage III, prototype development stage, while the LRC train did not. One reason is that the ICTS involved newer or previously untried technology, while the LRC train used technology which was mature or familiar to the firms involved. It can be argued that the fate of the Turbotrain was in large part due to its failure to build a prototype. This experience resulted in an extremely cautious approach being taken by the railways before they would accept the LRC train for commercial use. The time and the cost of the LRC project might have been shortened, if there had been a formal prototype stage with an understanding of what results had to be achieved at this stage. Of course, a successful prototype does not necessarily ensure a successful product in revenue operation.

The Stage IV Operational Demonstration is critical not only for technical but for marketing reasons. The LRC train has a problem here in that it cannot achieve its designed level of performance in terms of speed, not because of the train, but because of the inadequacy of the rest of the system. Meanwhile, other similar products, such as the French-built rapid train, which is system designed and developed, are getting more favourable publicity. The ICTS has not yet reached this stage, but it is noteworthy that the philosophy of UTDC has always been to stress the marketing aspects and the development of a system as the name implies.

The Management of Innovation

The literature on the management of innovation stresses the need for caution, and the strong likelihood that things will go wrong. It has even been suggested that with innovation Murphy's Law applies -- if anything

can go wrong it will, and at the worst possible time. Certainly the Turbotrain is consistent with Murphy's Law; the LRC train had its problems, such as funding for the project when the PAIT grant ran out before a marketable product had been produced, and the extended period of time before the train was introduced in revenue service in 1981; and the ICTS suffered a major setback when the West German government withdrew support for the 'maglev' technology of Krauss-Maffei on which the government of Ontario was basing its GO-URBAN system.

However, it must be recognised that innovation is an inherently risky process. In the private sector studies have shown that it takes a company an average of 58 new product ideas to come up with one successful new product.[7] Venture capitalists reckon on backing one successful entrepreneur out of every ten investments made. The question is to determine whether there are ways to manage the innovation process in order to reduce the risks. The literature provides references to the management pitfalls that exist, and some of these present a perspective on the ways in which risk might be reduced.

In a study of the management of large projects, Sayles and Chandler note:

> The shift from development to operations poses many problems. There is a good deal of evidence that even on the technical level the transition is not an easy one. There are always a whole new array of difficulties in translating successful innovations and prototypes to operational models. The need for continuity, for operation by less skilled or committed technicians, the impact of hostile environment factors; cost and maintenance problems,these and a host of other factors that are not present in the carefully insulated world of R&D can convert a successful experiment into

> a production disaster. Often a decade or more passes before a "proven" new technology is implemented successfully.[8]

Transitional problems can be expected in the case of the ICTS when introduced into Vancouver, and the LRC train has already experienced some difficulties in operation. The reference by Sayles and Chandler to problems of maintenance is particularly important. One reason for the failure of the Turbotrain was the lack of attention to problems of maintenance. This problem should not arise to the same extent in the case of the LRC train, because traditional railway technology is being used, and maintenance is being conducted by the railways as opposed to the equipment manufacturers. The managers of the ICTS need to be cognisant of this problem, especially if the technical expertise for maintenance is in Kingston and the system is operating in Vancouver.

Other items in the literature stress the need for tight management control of the project with a go/no-go decision having to be made at well-defined stages. The tendency is for a project to develop a head of steam and support from the group working on it. These people develop an overoptimistic view of the project and can frame the test results in a way which makes it difficult for their superiors to terminate the project. The literature suggests the need for strategic planning, with the management executing the plan "by adopting a framework of systems and procedures" which include the continual monitoring of the project. In addition, "an organizational environment that fosters attitudes of objectivity, confidence and enthusiasm on the part of individuals charged with implementation of the product

innovation effort is crucial".[9]

Both the ICTS and the LRC train had their enthusiastic supporters both within the companies working on the projects, and amongst the government officals associated with the funding and monitoring of the projects. The accountability procedures for both projects seemed to have been fairly well developed, especially as each project had at one point to justify further funding at a critical point in the process--the LRC train when PAIT funding ran out, and the ICTS when 'maglev' technology was found to be unsuitable.

An interesting feature of these two cases is that each appeared to have a political and bureaucratic sponsor as well as private sector sponsors. The LRC train was backed by the Department of Industry, Trade and Commerce, TDC and successive ministers of Transport, while the ICTS had throughout received the support of the Premier of Ontario, largely due to a close working relationship between the premier and the president of UTDC. This corporation has helped its political sponsor by explaining in reports and press releases exactly what it is doing and what its prospects are.

Although this system of sponsors seems to have worked well in these two instances, there is clearly a danger that it could backfire. Sponsors could become so committed to the project that they carry on when they should have stopped. For example,this seems to have been the case in a related instance, when the Ontario and federal governments continued their funding of Consolidated Computer Inc., to the tune of $120 million, when, in retrospect, it should have been terminated much earlier.

Another aspect of the management literature is relevant. D.A. Schon has discussed the fear which corporations have of innovation because it is destructive of the status quo within the corporation. The response of the corporation may include some of the following:[10]

1. It rejects the effort at innovation. It puts down the idea, fires or demotes the mer associated with it, and makes further discussion taboo. Many corporate pasts are littered with discarded efforts of this sort--begun, then stopped, then relegated to corporate limbo.

2. It allows the effort to continue, but isolates it from the rest of the corporation. In this way, research projects--or whole research departments--may function in a vacuum, cut off from the contacts that are essential to their ever coming to reality.

3. It contains the threat, allowing it to proceed, but on a level so much reduced that the innovation is always far short of critical mass.

4. It seeks to convert the threat to an activity acceptable within the corporate society. Efforts at radical innovation become product improvements or service to production or sales, which can be carried on without disrupting effect.

5. It may oscillate between support and resistance, confusing corporate members by an on-again, off-again approach to change.

6. It may resist innovation while not appearing to do so, while in fact proclaiming the official doctrine of innovation. For example, it may encourage the development of new product ideas only to find consistently that none of them meets the stringent criteria laid down in advance (just as a mother may want her son to get married but never approves of the girl he brings home); or it may foster a research effort, only to reject or ignore its results.

Examples of all these responses can be found in the case studies. Either certain officials in firms participating in the consortia would resist change, or some of the firms would withdraw their support or enthusiasm if the project did not progress to its liking, or the intended customer would be reluctant to cooperate. For example, it is alleged that certain groups within the railways tried to contain the forward progress of the LRC train, and to require ever more detailed and stringent criteria before accepting the train in commercial use.

In sum, there are two sets of attitudes to guard against, the over-enthusiasm which leads to continuing a project when it should be terminated, and the conservatism which tries to terminate it. A classic symptom of the latter is

> ...the reluctance of the railroads to adopt diesel locomotives because of the heavy commitment already made to steam. General Motors had to stimulate demand, in the end, by lending a diesel to a railroad for use in its switching yard. With this successful demonstration, railroads eventually bought diesels for yard use and, later on, for long-haul trains.[11]

Public Sector-Private Sector Relationships

Innovation in urban transportation is a highly political endeavour. The equipment is very visible and the service is used by large numbers of the electorate. The equipment is purchased by government, it is operated with government subsidies and its innovation is publicly funded. Private firms, however, get most of the equipment business, although they may bear very little of the risk of innovation. There are some similarities between innovation in defense and in urban transportation, but

the product of the former, although often more expensive, tends to be less visible and certainly less directly utilized by the public.

Governments have acted as venture capitalists and entrepreneurs in urban transportation, and, as such, have to expect to have more failures than successes. The visibility of the failures can be a source of considerable embarrassment, as in the case of the Turbotrain: this visibility tends to be much greater in urban transportation than in the defense area. In many ways, governments are not suited to be venture capitalists, because career rewards in the bureaucracy tend not to be associated with risking taxpayers revenues, but with the careful and prudent husbanding of these funds. However, governments are in the business of funding research and development through numerous programs so that the venture capital role, although uncomfortable at times, is not unique to urban transportation.

There is, however, one difference between government funding innovation in urban transportation as opposed to most other areas. The funding tends to be provided to a consortium of firms, as was the case for the LRC train and for the ICTS, and there is a problem ensuring that the members of the consortium work together harmoniously. Any project is likely to be of greater interest to some members than others, and it was noted in the case of the LRC train that different members of the consortium took the lead at different times. There is a further problem (already alluded to) that individuals within member firms may alter their enthusiasm for a project. This splintering of support becomes a greater problem the longer the project lasts

and the more deadlines are extended into the future. A related problem occurred in the ICTS project when Canadair, which had been contracted to be the project coordinator when its aircraft business was poor, decided to de-emphasise urban transportation when its traditional business recovered. The personnel within Canadair then had to be spun off and located in a UTDC subsidiary called Metro Canada Ltd.

The cases revealed three other features. First, urban transportation equipment is itself a conglomeration of component parts, which can be supplied by a wide variety of firms. This equipment can only work effectively if it is part of a well-designed system, for example,in conjunction with an appropriate roadbed and signalling system in the case of rail transportation. A systems approach means that there is a wide range of industrial benefits (spin-offs) to be collected and internalised within Canada, if firms are available as suppliers. The technology may have to be licensed from abroad, but as UTDC has shown, these benefits can be internalised as well. Second, if the projects are commercially acceptable for use in revenue operation, the return on the investment in innovation will depend on selling the products (systems) in foreign markets, especially the U.S. markets for the LRC train and the ICTS where similar standards are required.

And third, in Canada, the existence of the federal system means that there is competition between federal and provincial governments and between provincial governments, so that the innovative effort can become fragmented and costly. This was particularly noticeable where the federal government was supporting work by a

Quebec-based consortium on an ICTS at the same time that similar work was being done in Ontario. The operation of federalism was also responsible for neither Calgary nor Edmonton buying a Canadian-built light rail system, leading to a further fragmentation of the market which is a disincentive to innovation.

FOOTNOTES TO CHAPTER 6

1. See W.H. Gruber and D.G. Marquis, eds., Factors in The Transfer of Technology (Mass.: MIT Press, 1969).

2. Based on interviews with engineers.

3. Scherer, "The Aerospace Industry", op.cit., p. 335.

4. Ibid., p. 374.

5. See the following three Harvard Business Review articles: F.J. Andress, "The Learning Curve as a Production Tool" (Jan.-Feb. 1954); W.B. Herschmann, "Profit from the Learning Curve" (Jan.-Feb. 1964); W.J. Abernathy and K. Wayne, "Limits of the Learning Curve", (Sept.-Oct. 1974); also Boston Consulting Group, Perspectives on Experience (Boston, 1970); and J. Hirschleifer, "The Firm's Cost Function: A Successful Reconstruction", Journal of Business, Vol. 35, No. 3 (July 1962).

6. See references to literature in Chapter 1.

7. Booz, Allen and Hamilton, "A Program for New Product Evolution", in R.R. Rothberg, ed., Corporate Strategy and Product Innovation (2nd Ed.) (New York: Free Press, 1981), p. 8.

8. L.R. Sayles and M.K. Chandler, Managing Large Systems (New York: Harper & Row, 1971), pp. 136-137.

9. R.R. Rothberg, "Product Innovation in Perspective", in R.R. Rothberg, op.cit., p. 13.

10. D.A. Schon, "The Fear of Innovation", International Science and Technology, 14 (Nov. 1966), pp. 70-78.

11. Rothberg, op.cit., p. 17.